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(54) Title: NANBV DIAGNOSTICS AND VACCINES

(57) Abstract

A new virus, Hepatitis C virus (HCV), which has proven to be the major etiologic agent of blood-borne NANBH, was discovered by Applicant. The initial work on this virus, which includes a partial genomic sequence of the prototype HCV isolate, is described in EPO Pub. No. 318,216, and PCT Pub. No. WO 89/04669. The present invention, which in part is based on new HCV sequences and polypeptides which are not disclosed in the above-cited publications, includes the application of these new sequences and polypeptides in immunoassays, probe diagnostics, anti-HCV antibody production, PCR technology, and recombinant DNA technology. Included within the invention also are novel, immunogenic polypeptides encoded within clones containing HCV cDNA, novel methods for purifying an immunogenic HCV polypeptide, and antisense polynucleotides derived from HCV cDNA.

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NANBV DIAGNOSTICS AND VACCINES10 Technical Field

The invention relates to materials and methodologies for managing the spread of non-A, non-B hepatitis virus (NANBV) infection. More specifically, it relates to polynucleotides derived from the genome of an etiologic agent of NANBV, hepatitis C virus (HCV), to polypeptides encoded therein, and to antibodies directed to the polypeptides. These reagents are useful as screening agents for HCV and its infection, and as protective agents against the disease.

20

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 PCT Pub. No. WO 89/04669
 U.S. Patent No. 4,341,761
 U.S. Patent No. 4,399,121
 U.S. Patent No. 4,427,783
 U.S. Patent No. 4,444,887
 U.S. Patent No. 4,466,917
10 U.S. Patent No. 4,472,500
 U.S. Patent No. 4,491,632
 U.S. Patent No. 4,493,890

Background Art

15 Non-A, Non-B hepatitis (NANBH) is a
 transmissible disease or family of diseases that are
 believed to be viral-induced, and that are distinguishable
 from other forms of viral-associated liver diseases,
 including that caused by the known hepatitis viruses,
20 i.e., hepatitis A virus (HAV), hepatitis B virus (HBV),
 and delta hepatitis virus (HDV), as well as the hepatitis
 induced by cytomegalovirus (CMV) or Epstein-Barr virus
 (EBV). NANBH was first identified in transfused
 individuals. Transmission from man to chimpanzee and se-
25 rial passage in chimpanzees provided evidence that NANBH
 is due to a transmissible infectious agent or agents.

30 Epidemiologic evidence is suggestive that there
 may be three types of NANBH: the water-borne epidemic
 type; the blood or needle associated type; and the
 sporadically occurring (community acquired) type.
 However, the number of agents which may be the causative
 of NANBH are unknown.

35 Clinical diagnosis and identification of NANBH
 has been accomplished primarily by exclusion of other
 viral markers. Among the methods used to detect putative
 NANBV antigens and antibodies are agar-gel diffusion,

counterimmunolectrophoresis, immunofluorescence microscopy, immune electron microscopy, radioimmunoassay, and enzyme-linked immunosorbent assay. However, none of 5 these assays has proved to be sufficiently sensitive, specific, and reproducible to be used as a diagnostic test for NANBH.

Previously there was neither clarity nor agreement as to the identity or specificity of the antigen 10 antibody systems associated with agents of NANBH. This was due, at least in part, to the prior or co-infection of HBV with NANBV in individuals, and to the known complexity of the soluble and particulate antigens associated with HBV, as well as to the integration of HBV DNA into the 15 genome of liver cells. In addition, there is the possibility that NANBH is caused by more than one infectious agent, as well as the possibility that NANBH has been misdiagnosed. Moreover, it is unclear what the serological assays detect in the serum of patients with NANBH. It has 20 been postulated that the agar-gel diffusion and counterimmunolectrophoresis assays detect autoimmune responses or nonspecific protein interactions that sometimes occur between serum specimens, and that they do not represent specific NANBV antigen-antibody reactions. The 25 immunofluorescence, and enzyme-linked immunosorbent, and radioimmunoassays appear to detect low levels of a rheumatoid-factor-like material that is frequently present in the serum of patients with NANBH as well as in patients with other hepatic and nonhepatic diseases. Some of the 30 reactivity detected may represent antibody to host-determined cytoplasmic antigens.

There have been a number of candidate NANBV. See, for example the reviews by Prince (1983), Feinstone and Hoofnagle (1984), and Overby (1985, 1986, 1987) and 35 the article by Iwarson (1987). However, there is no proof

that any of these candidates represent the etiological agent of NANBH.

5 The demand for sensitive, specific methods for screening and identifying carriers of NANBV and NANBV contaminated blood or blood products is significant. Post-transfusion hepatitis (PTH) occurs in approximately 10% of transfused patients, and NANBH accounts for up to 10 90% of these cases. The major problem in this disease is the frequent progression to chronic liver damage (25-55%).

15 Patient care as well as the prevention of transmission of NANBH by blood and blood products or by close personal contact require reliable screening, diagnostic and prognostic tools to detect nucleic acids, antigens and antibodies related to NANBV. In addition, there is also a need for effective vaccines and immunotherapeutic therapeutic agents for the prevention and/or treatment of the disease.

20 Applicant discovered a new virus, the Hepatitis C virus (HCV), which has proven to be the major etiologic agent of blood-borne NANBH (BB-NANBH). Applicant's initial work, including a partial genomic sequence of the prototype HCV isolate, CDC/HCV1 (also called HCV1), is described in EPO Pub. No. 318,216 (published 31 May 1989) and PCT Pub. No. WO 89/04669 (published 1 June 1989). The disclosures of these patent applications, as well as any corresponding national patent applications, are incorporated herein by reference. These applications teach, 25 inter alia, recombinant DNA methods of cloning and expressing HCV sequences, HCV polypeptides, HCV immunodiagnostic techniques, HCV probe diagnostic techniques, anti-HCV antibodies, and methods of isolating new hCV sequences, including sequences of new HCV isolates.

30

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Disclosure of the Invention

The present invention is based, in part, on new HCV sequences and polypeptides that are not disclosed in 5 EPO Pub. No. 318,216, or in PCT Pub. No. WO 89/04669. Included within the invention is the application of these new sequences and polypeptides in, *inter alia*, immunodiagnostics, probe diagnostics, anti-HCV antibody production, PCR technology and recombinant DNA technology. 10 Included within the invention, also, are new immunoassays based upon the immunogenicity of HCV polypeptides disclosed herein. The new subject matter claimed herein, while developed using techniques described in, for example, EPO Pub. No. 318,216, has a priority date which 15 antecedes that publication, or any counterpart thereof. Thus, the invention provides novel compositions and methods useful for screening samples for HCV antigens and antibodies, and useful for treatment of HCV infections.

Accordingly, one aspect of the invention is a 20 recombinant polynucleotide comprising a sequence derived from HCV cDNA, wherein the HCV cDNA is in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pi14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or 25 clone 16jh, or wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17.

Another aspect of the invention is a purified 30 polypeptide comprising an epitope encoded within HCV cDNA wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17.

Yet another aspect of the invention is an immunogenic polypeptide produced by a cell transformed with 35 a recombinant expression vector comprising an ORF of DNA derived from HCV cDNA, wherein the HCV cDNA is comprised

of a sequence derived from the HCV cDNA sequence in clone CA279a, or clone CA74a, or clone 13i, or clone CA290a, or clone 33C or clone 40b, or clone 33b, or clone 25c, or 5 clone 14c, or clone 8f, or clone 33f, or clone 33g, or clone 39c, or clone 15e, and wherein the ORF is operably linked to a control sequence compatible with a desired host.

10 Another aspect of the invention is a peptide comprising an HCV epitope, wherein the peptide is of the formula

AA_x-AA_y,

15 wherein x and y designate amino acid numbers shown in Fig. 17, and wherein the peptide is selected from the group consisting of AA1-AA25, AA1-AA50, AA1-AA84, AA9-AA177, AA1-AA10, AA5-AA20, AA20-AA25, AA35-AA45, AA50-AA100, AA40-AA90, AA45-AA65, AA65-AA75, AA80-90, AA99-AA120, 20 AA95-AA110, AA105-AA120, AA100-AA150, AA150-AA200, AA155-AA170, AA190-AA210, AA200-AA250, AA220-AA240, AA245-AA265, AA250-AA300, AA290-AA330, AA290-305, AA300-AA350, AA310-AA330, AA350-AA400, AA380-AA395, AA405-AA495, AA400-AA450, AA405-AA415, AA415-AA425, 25 AA425-AA435, AA437-AA582, AA450-AA500, AA440-AA460, AA460-AA470, AA475-AA495, AA500-AA550, AA511-AA690, AA515-AA550, AA550-AA600, AA550-AA625, AA575-AA605, AA585-AA600, AA600-AA650, AA600-AA625, AA635-AA665, AA650-AA700, AA645-AA680, AA700-AA750, AA700-AA725, AA700-AA750, 30 AA725-AA775, AA770-AA790, AA750-AA800, AA800-AA815, AA825-AA850, AA850-AA875, AA800-AA850, AA920-AA990, AA850-AA900, AA920-AA945, AA940-AA965, AA970-AA990, AA950-AA1000, AA1000-AA1060, AA1000-AA1025, AA1000-AA1050, AA1025-AA1040, AA1040-AA1055, AA1075-AA1175, 35 AA1050-AA1200, AA1070-AA1100, AA1100-AA1130, AA1140-AA1165, AA1192-AA1457, AA1195-AA1250,

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AA1260-AA1310, AA1260-AA1280, AA1266-AA1428,
5 AA1300-AA1350, AA1290-AA1310, AA1310-AA1340, AA1345-
AA1405, AA1345-AA1365, AA1350-AA1400, AA1365-AA1380,
AA1380-AA1405, AA1400-AA1450, AA1450-AA1500,
AA1460-AA1475, AA1475-AA1515, AA1475-AA1500,
AA1500-AA1550, AA1500-AA1515, AA1515-AA1550,
AA1550-AA1600, AA1545-AA1560, AA1569-AA1931,
10 AA1570-AA1590, AA1595-AA1610, AA1590-AA1650,
AA1610-AA1645, AA1650-AA1690, AA1685-AA1770,
AA1689-AA1805, AA1690-AA1720, AA1694-AA1735,
AA1720-AA1745, AA1745-AA1770, AA1750-AA1800,
AA1775-AA1810, AA1795-AA1850, AA1850-AA1900,
15 AA1900-AA1950, AA1900-AA1920, AA1916-AA2021,
AA1920-AA1940, AA1949-AA2124, AA1950-AA2000,
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AA2005-AA2025, AA2020-AA2045, AA2045-AA2100,
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20 AA2100-AA2150, AA2150-AA2200, AA2200-AA2250,
AA2200-AA2325, AA2250-AA2330, AA2255-AA2270,
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AA2300-AA2350, AA2290-AA2310, AA2310-AA2330,
AA2330-AA2350, AA2350-AA2400, AA2348-AA2464,
25 AA2345-AA2415, AA2345-AA2375, AA2370-AA2410,
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30 AA2600-AA2650, AA2605-AA2620, AA2620-AA2650,
AA2640-AA2660, AA2650-AA2700, AA2655-AA2670,
AA2670-AA2700, AA2700-AA2750, AA2740-AA2760,
AA2750-AA2800, AA2755-AA2780,
AA2780-AA2830, AA2785-AA2810, AA2796-AA2886,
35 AA2810-AA2825, AA2800-AA2850, AA2850-AA2900,

AA2850-AA2865, AA2885-AA2905, AA2900-AA2950,
AA2910-AA2930, AA2925-AA2950, AA2945-end(C' terminal).

5 Still another aspect of the invention is a monoclonal antibody directed against an epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 10 167b, or clone pi14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh.

15 Yet another aspect of the invention is a preparation of purified polyclonal antibodies directed against a polypeptide comprised of an epitope encoded within HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone 20 CA156e, or clone 167b, or clone pi14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh.

25 Still another aspect of the invention is a polynucleotide probe for HCV, wherein the probe is comprised of an HCV sequence derived from an HCV cDNA sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or from the complement of the HCV cDNA sequence.

30 Yet another aspect of the invention is a kit for analyzing samples for the presence of polynucleotides from HCV comprising a polynucleotide probe containing a nucleotide sequence of about 8 or more nucleotides, wherein the nucleotide sequence is derived from HCV cDNA which is of a sequence indicated by nucleotide numbers - 35 319 to 1348 or 8659 to 8866 in Fig. 17, wherein the polynucleotide probe is in a suitable container.

Another aspect of the invention is a kit for analyzing samples for the presence of an HCV antigen comprising an antibody which reacts immunologically with an HCV antigen, wherein the antigen contains an epitope encoded within HCV cDNA which is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or wherein the HCV cDNA is in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pi14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh.

5 Yet another aspect of the invention is a kit for analyzing samples for the presence of an HCV antibody comprising an antigenic polypeptide containing an HCV epitope encoded within HCV cDNA which is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pi14a, or clone CA216a, or clone CA290a, or clone 20 20 ag30a, or clone 205a, or clone 18g, or clone 16jh.

Another aspect of the invention is a kit for analyzing samples for the presence of an HCV antibody comprising an antigenic polypeptide expressed from HCV cDNA in clone CA279a, or clone CA74a, or clone 13i, or clone CA290a, or clone 33C or clone 40b, or clone 33b, or clone 25c, or clone 14c, or clone 8f, or clone 33f, or clone 33g, or clone 39c, or clone 15e, wherein the antigenic polypeptide is present in a suitable container.

30 Still another aspect of the invention is a method for detecting HCV nucleic acids in a sample comprising:

(a) reacting nucleic acids of the sample with a polynucleotide probe for HCV, wherein the probe is comprised of an HCV sequence derived from an HCV cDNA sequence is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, and wherein the

reacting is under conditions which allow the formation of a polynucleotide duplex between the probe and the HCV nucleic acid from the sample; and (b) detecting a polynucleotide duplex which contains the probe, formed in step (a).

5 Yet another aspect of the invention is an immunoassay for detecting an HCV antigen comprising:

10 (a) incubating a sample suspected of containing an HCV antigen with an antibody directed against an HCV epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pil4a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, and wherein the incubating is under conditions which allow formation of an antigen-antibody complex; and (b) detecting an antibody-antigen complex formed in step (a) which contains the antibody.

15 20 Still another aspect of the invention is an immunoassay for detecting antibodies directed against an HCV antigen comprising:

25 (a) incubating a sample suspected of containing anti-HCV antibodies with an antigen polypeptide containing an epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pil4a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, and wherein the incubating is under conditions which allow formation of an antigen-antibody complex; and detecting an antibody-antigen complex formed in step (a) which contains the antigen polypeptide.

Another aspect of the invention is a vaccine for treatment of HCV infection comprising an immunogenic polypeptide containing an HCV epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17 or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone p14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, and wherein the immunogenic polypeptide is present in a pharmacologically effective dose in a pharmaceutically acceptable excipient.

Yet another aspect of the invention is a method for producing antibodies to HCV comprising administering to an individual an isolated immunogenic polypeptide containing an HCV epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is of the sequence present in clone CA279a, or clone CA74a, or clone 13i, or clone CA290a, or clone 33C or clone 40b, or clone 33b, or clone 25c, or clone 14c, or clone 8f, or clone 33f, or clone 33g, or clone 39c, or clone 15e, and wherein the immunogenic polypeptide is present in a pharmacologically effective dose in a pharmaceutically acceptable excipient.

Still another aspect of the invention is an antisense polynucleotide derived from HCV cDNA, wherein the HCV cDNA is that shown in Fig. 17.

Yet another aspect of the invention is a method for preparing purified fusion polypeptide C100-3 comprising:

(a) providing a crude cell lysate containing polypeptide C100-3,

(b) treating the crude cell lysate with an amount of acetone which causes the polypeptide to precipitate,

5 (c) isolating and solubilizing the precipitated material,

(d) isolating the C100-3 polypeptide by anion exchange chromatography, and

10 (e) further isolating the C100-3 polypeptide of step (d) by gel filtration.

Brief Description of the Drawings

15 Fig. 1 shows the sequence of the HCV cDNA in clone 12f, and the amino acids encoded therein.

Fig. 2 shows the HCV cDNA sequence in clone k9-1, and the amino acids encoded therein.

20 Fig. 3 shows the sequence of clone 15e, and the amino acids encoded therein.

Fig. 4 shows the nucleotide sequence of HCV cDNA in clone 13i, the amino acids encoded therein, and the sequences which overlap with clone 12f.

25 Fig. 5 shows the nucleotide sequence of HCV cDNA in clone 26j, the amino acids encoded therein, and the sequences which overlap clone 13i.

Fig. 6 shows the nucleotide sequence of HCV cDNA in clone CA59a, the amino acids encoded therein, and the sequences which overlap with clones 26j and K9-1.

30 Fig. 7 shows the nucleotide sequence of HCV cDNA in clone CA84a, the amino acids encoded therein, and the sequences which overlap with clone CA59a.

35 Fig. 8 shows the nucleotide sequence of HCV cDNA in clone CA156e, the amino acids encoded therein, and the sequences which overlap with CA84a.

Fig. 9 shows the nucleotide sequence of HCV cDNA in clone CA167b, the amino acids encoded therein, and the sequences which overlap CA156e.

Fig. 10 shows the nucleotide sequence of HCV cDNA in clone CA216a, the amino acids encoded therein, and the overlap with clone CA167b.

Fig. 11 shows the nucleotide sequence of HCV cDNA in clone CA290a, the amino acids encoded therein, and the overlap with clone CA216a.

10 Fig. 12 shows the nucleotide sequence of HCV cDNA in clone ag30a and the overlap with clone CA290a.

Fig. 13 shows the nucleotide sequence of HCV cDNA in clone CA205a, and the overlap with the HCV cDNA sequence in clone CA290a.

15 Fig. 14 shows the nucleotide sequence of HCV cDNA in clone 18g, and the overlap with the HCV cDNA sequence in clone ag30a.

20 Fig. 15 shows the nucleotide sequence of HCV cDNA in clone 16jh, the amino acids encoded therein, and the overlap of nucleotides with the HCV cDNA sequence in clone 15e.

Fig. 16 shows the ORF of HCV cDNA derived from clones pi14a, CA167b, CA156e, CA84a, CA59a, K9-1, 12f, 14i, 11b, 7f, 7e, 8h, 33c, 40b, 37b, 35, 36, 81, 32, 33b, 25c, 14c, 8f, 33f, 33g, 39c, 35f, 19g, 26g, and 15e.

Fig. 17 shows the sense strand of the compiled HCV cDNA sequence derived from the above-described clones and the compiled HCV cDNA sequence published in EPO Pub. No. 318,216. The clones from which the sequence was derived are b114a, 18g, ag30a, CA205a, CA290a, CA216a, pi14a, CA167b, CA156e, CA84a, CA59a, K9-1 (also called k9-1), 26j, 13i, 12f, 14i, 11b, 7f, 7e, 8h, 33c, 40b, 37b, 35, 36, 81, 32, 33b, 25c, 14c, 8f, 33f, 33g, 39c, 35f, 19g, 26g, 15e, b5a, and 16jh. In the figure the three horizontal dashes above the sequence indicate the position

5 of the putative initiator methionine codon; the two vertical dashes indicate the first and last nucleotides of the published sequence. Also shown in the figure is the amino acid sequence of the putative polyprotein encoded in the HCV cDNA.

Fig. 18 is a diagram of the immunological colony screening method used in antigenic mapping studies.

10 Fig. 19 shows the hydrophobicity profiles of polyproteins encoded in HCV and in West Nile virus.

Fig. 20 is a tracing of the hydrophilicity/hydrophobicity profile and of the antigenic index of the putative HCV polyprotein.

15 Fig. 21 shows the conserved co-linear peptides in HCV and Flaviviruses.

Modes for Carrying Out the Invention

20 I. Definitions

The term "hepatitis C virus" has been reserved by workers in the field for an heretofore unknown etiologic agent of NANBH. Accordingly, as used herein, "hepatitis C virus" (HCV) refers to an agent causitive of NANBH, which was formerly referred to as NANBV and/or BB-NANBV. The terms HCV, NANBV, and BB-NANBV are used interchangeably herein. As an extension of this terminology, the disease caused by HCV, formerly called NANB hepatitis (NANBH), is called hepatitis C. The terms NANBH and hepatitis C may be used interchangeably herein.

25 The term "HCV", as used herein, denotes a viral species of which pathogenic strains cause NANBH, and attenuated strains or defective interfering particles derived therefrom. As shown infra., the HCV genome is 30 comprised of RNA. It is known that RNA containing viruses have relatively high rates of spontaneous mutation, i.e., 35 reportedly on the order of 10^{-3} to 10^{-4} per incorporated

5 nucleotide (Fields & Knipe (1986)). Therefore, there are multiple strains, which may be virulent or avirulent, within the HCV species described infra. The compositions and methods described herein, enable the propagation, identification, detection, and isolation of the various HCV strains or isolates. Moreover, the disclosure herein allows the preparation of diagnostics and vaccines for the various strains, as well as compositions and methods that 10 have utility in screening procedures for anti-viral agents for pharmacologic use, such as agents that inhibit replication of HCV.

15 The information provided herein, although derived from the prototype strain or isolate of HCV, hereinafter referred to as CDC/HCV1 (also called HCV1), is sufficient to allow a viral taxonomist to identify other strains which fall within the species. The information provided herein allows the belief that HCV is a Flavi-like virus. The morphology and composition of Flavivirus 20 particles are known, and are discussed in Brinton (1986). Generally, with respect to morphology, Flaviviruses contain a central nucleocapsid surrounded by a lipid bilayer. Virions are spherical and have a diameter of about 40-50 nm. Their cores are about 25-30 nm in 25 diameter. Along the outer surface of the virion envelope are projections that are about 5-10 nm long with terminal knobs about 2 nm in diameter.

30 Different strains or isolates of HCV are expected to contain variations at the amino acid and 35 nucleic acids compared with the prototype isolate, HCV1. Many isolates are expected to show much (i.e. more than about 40%) homology in the total amino acid sequence compared with HCV1. However, it may also be found that other less homologous HCV isolates. These would be defined as HCV strains according to various criteria such as an ORF of approximately 9,000 nucleotides to ap-

proximately 12,000 nucleotides, encoding a polyprotein similar in size to that of HCV1, an encoded polyprotein of similar hydrophobic and antigenic character to that of HCV1, and the presence of co-linear peptide sequences that are conserved with HCV1. In addition, the genome would be a positive-stranded RNA.

HCV encodes at least one epitope which is immunologically identifiable with an epitope in the HCV genome from which the cDNAs described herein are derived; preferably the epitope is contained an amino acid sequence described herein. The epitope is unique to HCV when compared to other known Flaviviruses. The uniqueness of the epitope may be determined by its immunological reactivity with anti-HCV antibodies and lack of immunological reactivity with antibodies to other Flavivirus species. Methods for determining immunological reactivity are known in the art, for example, by radioimmunoassay, by Elisa assay, by hemagglutination, and several examples of suitable techniques for assays are provided herein.

In addition to the above, the following parameters of nucleic acid homology and amino acid homology are applicable, either alone or in combination, in identifying a strain or isolate as HCV. Since HCV strains and isolates are evolutionarily related, it is expected that the overall homology of the genomes at the nucleotide level probably will be about 40% or greater, probably about 60% or greater, and even more probably about 80% or greater; and in addition that there will be corresponding contiguous sequences of at least about 13 nucleotides. The correspondence between the putative HCV strain genomic sequence and the CDC/HCV1 cDNA sequence can be determined by techniques known in the art. For example, they can be determined by a direct comparison of the sequence information of the polynucleotide from the putative HCV, and the HCV cDNA sequence(s) described herein. For example, also,

they can be determined by hybridization of the polynucleotides under conditions which form stable duplexes between homologous regions (for example, those 5 which would be used prior to S_1 digestion), followed by digestion with single stranded specific nuclease(s), followed by size determination of the digested fragments.

Because of the evolutionary relationship of the strains or isolates of HCV, putative HCV strains or 10 isolates are identifiable by their homology at the polypeptide level. Generally, HCV strains or isolates are expected to be more than about 40% homologous, probably more than about 70% homologous, and even more probably more than about 80% homologous, and some may even be more 15 than about 90% homologous at the polypeptide level. The techniques for determining amino acid sequence homology are known in the art. For example, the amino acid sequence may be determined directly and compared to the sequences provided herein. Alternatively the nucleotide 20 sequence of the genomic material of the putative HCV may be determined (usually via a cDNA intermediate), the amino acid sequence encoded therein can be determined, and the corresponding regions compared.

As used herein, a polynucleotide "derived from" 25 a designated sequence refers to a polynucleotide sequence which is comprised of a sequence of approximately at least about 6 nucleotides, preferably at least about 8 nucleotides, more preferably at least about 10-12 nucleotides, and even more preferably at least about 15-20 30 nucleotides corresponding to a region of the designated nucleotide sequence. "Corresponding" means homologous to or complementary to the designated sequence. Preferably, the sequence of the region from which the polynucleotide is derived is homologous to or complementary to a sequence 35 which is unique to an HCV genome. Whether or not a sequence is unique to the HCV genome can be determined by

techniques known to those of skill in the art. For example, the sequence can be compared to sequences in databanks, e.g., Genebank, to determine whether it is 5 present in the uninfected host or other organisms. The sequence can also be compared to the known sequences of other viral agents, including those which are known to induce hepatitis, e.g., HAV, HBV, and HDV, and to other members of the Flaviviridae. The correspondence or non- 10 correspondence of the derived sequence to other sequences can also be determined by hybridization under the appropriate stringency conditions. Hybridization techniques for determining the complementarity of nucleic acid sequences are known in the art, and are discussed infra. 15 See also, for example, Maniatis et al. (1982). In addition, mismatches of duplex polynucleotides formed by hybridization can be determined by known techniques, including for example, digestion with a nuclease such as S1 that specifically digests single-stranded areas in 20 duplex polynucleotides. Regions from which typical DNA sequences may be "derived" include but are not limited to, for example, regions encoding specific epitopes, as well as non-transcribed and/or non-translated regions.

25 The derived polynucleotide is not necessarily physically derived from the nucleotide sequence shown, but may be generated in any manner, including for example, chemical synthesis or DNA replication or reverse transcription or transcription. In addition, combinations of regions corresponding to that of the designated 30 sequence may be modified in ways known in the art to be consistent with an intended use.

35 Similarly, a polypeptide or amino acid sequence "derived from" a designated nucleic acid sequence refers to a polypeptide having an amino acid sequence identical to that of a polypeptide encoded in the sequence, or a portion thereof wherein the portion consists of at least

3-5 amino acids, and more preferably at least 8-10 amino acids, and even more preferably at least 11-15 amino acids, or which is immunologically identifiable with a 5 polypeptide encoded in the sequence.

A recombinant or derived polypeptide is not necessarily translated from a designated nucleic acid sequence, for example, the HCV cDNA sequences described herein, or from an HCV genome; it may be generated in any 10 manner, including for example, chemical synthesis, or expression of a recombinant expression system, or isolation from mutated HCV. A recombinant or derived polypeptide may include one or more analogs of amino acids or unnatural amino acids in its sequence. Methods of 15 inserting analogs of amino acids into a sequence are known in the art. It also may include one or more labels, which are known to those of skill in the art.

The term "recombinant polynucleotide" as used 20 herein intends a polynucleotide of genomic, cDNA, semisynthetic, or synthetic origin which, by virtue of its origin or manipulation which: (1) is not associated with all or a portion of a polynucleotide with which it is associated in nature, (2) is linked to a polynucleotide other than that to which it is linked in nature, or (3) 25 does not occur in nature.

The term "polynucleotide" as used herein refers 30 to a polymeric form of nucleotides of any length, either ribonucleotides or deoxyribonucleotides. This term refers only to the primary structure of the molecule. Thus, this term includes double- and single-stranded DNA, as well as double- and single stranded RNA. It also includes known types of modifications, for example, labels which are known in the art, methylation, "caps", substitution of one 35 or more of the naturally occurring nucleotides with an analog, internucleotide modifications such as, for example, those with uncharged linkages (e.g., methyl

5 phosphonates, phosphotriesters, phosphoamidates, carbamates, etc.) and with charged linkages (e.g., phosphorothioates, phosphorodithioates, etc.), those
10 containing pendant moieties, such as, for example proteins (including for e.g., nucleases, toxins, antibodies, signal peptides, poly-L-lysine, etc.), those with intercalators (e.g., acridine, psoralen, etc.), those containing chelators (e.g., metals, radioactive metals, boron, oxidative metals, etc.), those containing alkylators, those with modified linkages (e.g., alpha anomeric nucleic acids, etc.), as well as unmodified forms of the polynucleotide.

15 The term "purified viral polynucleotide" refers to an HCV genome or fragment thereof which is essentially free, i.e., contains less than about 50%, preferably less than about 70%, and even more preferably less than about 90% of polypeptides with which the viral polynucleotide is naturally associated. Techniques for purifying viral
20 polynucleotides from viral particles are known in the art, and include for example, disruption of the particle with a chaotropic agent, differential extraction and separation of the polynucleotide(s) and polypeptides by ion-exchange chromatography, affinity chromatography, and sedimentation
25 according to density.

30 The term "purified viral polypeptide" refers to an HCV polypeptide or fragment thereof which is essentially free, i.e., contains less than about 50%, preferably less than about 70%, and even more preferably less than about 90%, of cellular components with which the viral polypeptide is naturally associated. Techniques for purifying viral polypeptides are known in the art, and examples of these techniques are discussed infra. The term
35 "purified viral polynucleotide" refers to an HCV genome or fragment thereof which is essentially free, i.e., contains less than about 20%, preferably less than about 50%, and

even more preferably less than about 70% of polypeptides with which the viral polynucleotide is naturally associated. Techniques for purifying viral polynucleotides from 5 viral particles are known in the art, and include for example, disruption of the particle with a chaotropic agent, and separation of the polynucleotide(s) and polypeptides by ion-exchange chromatography, affinity chromatography, and sedimentation according to density.

10 "Recombinant host cells", "host cells", "cells", "cell lines", "cell cultures", and other such terms denoting microorganisms or higher eukaryotic cell lines cultured as unicellular entities refer to cells which can be, or have been, used as recipients for recombinant vector or other transfer DNA, and include the progeny of the 15 original cell which has been transfected. It is understood that the progeny of a single parental cell may not necessarily be completely identical in morphology or 20 in genomic or total DNA complement as the original parent, due to natural, accidental, or deliberate mutation.

25 A "replicon" is any genetic element, e.g., a plasmid, a chromosome, a virus, a cosmid, etc. that behaves as an autonomous unit of polynucleotide replication within a cell; i.e., capable of replication under its own control.

A "vector" is a replicon in which another polynucleotide segment is attached, so as to bring about the replication and/or expression of the attached segment.

30 "Control sequence" refers to polynucleotide sequences which are necessary to effect the expression of coding sequences to which they are ligated. The nature of such control sequences differs depending upon the host organism; in prokaryotes, such control sequences generally 35 include promoter, ribosomal binding site, and terminators; in eukaryotes, generally, such control sequences include promoters, terminators and, in some instances, enhancers.

5 The term "control sequences" is intended to include, at a minimum, all components whose presence is necessary for expression, and may also include additional components whose presence is advantageous, for example, leader sequences.

10 "Operably linked" refers to a juxtaposition wherein the components so described are in a relationship permitting them to function in their intended manner. A control sequence "operably linked" to a coding sequence is ligated in such a way that expression of the coding sequence is achieved under conditions compatible with the control sequences.

15 An "open reading frame" (ORF) is a region of a polynucleotide sequence which encodes a polypeptide; this region may represent a portion of a coding sequence or a total coding sequence. 809

20 A "coding sequence" is a polynucleotide sequence which is transcribed into mRNA and/or translated into a polypeptide when placed under the control of appropriate regulatory sequences. The boundaries of the coding sequence are determined by a translation start codon at the 5'-terminus and a translation stop codon at the 3'-terminus. A coding sequence can include, but is not limited to mRNA, cDNA, and recombinant polynucleotide sequences.

25 30 "Immunologically identifiable with/as" refers to the presence of epitope(s) and polypeptides(s) which are also present in the designated polypeptide(s), usually HCV proteins. Immunological identity may be determined by antibody binding and/or competition in binding; these techniques are known to those of average skill in the art, and are also illustrated infra.

35 As used herein, "epitope" refers to an antigenic determinant of a polypeptide; an epitope could comprise 3 amino acids in a spatial conformation which is unique to

the epitope, generally an epitope consists of at least 5 such amino acids, and more usually, consists of at least 8-10 such amino acids. Methods of determining the spatial 5 conformation of amino acids are known in the art, and include, for example, x-ray crystallography and 2-dimensional nuclear magnetic resonance.

A polypeptide is "immunologically reactive" with 10 an antibody when it binds to an antibody due to antibody recognition of a specific epitope contained within the polypeptide. Immunological reactivity may be determined by antibody binding, more particularly by the kinetics of antibody binding, and/or by competition in binding using 15 as competitor(s) a known polypeptide(s) containing an epitope against which the antibody is directed. The techniques for determining whether a polypeptide is immunologically reactive with an antibody are known in the art.

20 As used herein, the term "immunogenic polypeptide" is a polypeptide that elicits a cellular and/or humoral response, whether alone or linked to a carrier in the presence or absence of an adjuvant.

The term "polypeptide" refers to a polymer of 25 amino acids and does not refer to a specific length of the product; thus, peptides, oligopeptides, and proteins are included within the definition of polypeptide. This term also does not refer to or exclude post-expression 30 modifications of the polypeptide, for example, glycosylations, acetylations, phosphorylations and the like. Included within the definition are, for example, polypeptides containing one or more analogs of an amino acid (including, for example, unnatural amino acids, etc.), polypeptides with substituted linkages, as well as 35 other modifications known in the art, both naturally occurring and non-naturally occurring.

5 "Transformation", as used herein, refers to the insertion of an exogenous polynucleotide into a host cell, irrespective of the method used for the insertion, for example, direct uptake, transduction, f-mating or electroporation. The exogenous polynucleotide may be maintained as a non-integrated vector, for example, a plasmid, or alternatively, may be integrated into the host genome.

10 "Treatment" as used herein refers to prophylaxis and/or therapy.

15 An "individual", as used herein, refers to vertebrates, particularly members of the mammalian species, and includes but is not limited to domestic animals, sports animals, and primates, including humans.

20 As used herein, the "sense strand" of a nucleic acid contains the sequence that has sequence homology to that of mRNA. The "anti-sense strand" contains a sequence which is complementary to that of the "sense strand".

25 As used herein, a "positive stranded genome" of a virus is one in which the genome, whether RNA or DNA, is single-stranded and which encodes a viral polypeptide(s). Examples of positive stranded RNA viruses include Togaviridae, Coronaviridae, Retroviridae, Picornaviridae, and Caliciviridae. Included also, are the Flaviviridae, which were formerly classified as Togaviradae. See Fields & Knipe (1986).

30 As used herein, "antibody-containing body component" refers to a component of an individual's body which is a source of the antibodies of interest. Antibody containing body components are known in the art, and include but are not limited to, for example, plasma, serum, spinal fluid, lymph fluid, the external sections of the respiratory, intestinal, and genitourinary tracts, tears, saliva, milk, white blood cells, and myelomas.

As used herein, "purified HCV" refers to a preparation of HCV which has been isolated from the cellular constituents with which the virus is normally associated, and from other types of viruses which may be present in the infected tissue. The techniques for isolating viruses are known to those of skill in the art, and include, for example, centrifugation and affinity chromatography; a method of preparing purified HCV is discussed infra.

The term "HCV particles" as used herein include entire virion as well as particles which are intermediates in virion formation. HCV particles generally have one or more HCV proteins associated with the HCV nucleic acid.

As used herein, the term "probe" refers to a polynucleotide which forms a hybrid structure with a sequence in a target region, due to complementarity of at least one sequence in the probe with a sequence in the target region. The probe, however, does not contain a sequence complementary to sequence(s) used to prime the polymerase chain reaction.

As used herein, the term "target region" refers to a region of the nucleic acid which is to be amplified and/or detected.

As used herein, the term "viral RNA", which includes HCV RNA, refers to RNA from the viral genome, fragments thereof, transcripts thereof, and mutant sequences derived therefrom.

As used herein, a "biological sample" refers to a sample of tissue or fluid isolated from an individual, including but not limited to, for example, plasma, serum, spinal fluid, lymph fluid, the external sections of the skin, respiratory, intestinal, and genitourinary tracts, tears, saliva, milk, blood cells, tumors, organs, and also samples of in vitro cell culture constituents (including but not limited to conditioned medium resulting from the

growth of cells in cell culture medium, putatively virally infected cells, recombinant cells, and cell components).

5 III. Description of the Invention

The practice of the present invention will employ, unless otherwise indicated, conventional techniques of molecular biology, microbiology, recombinant DNA, and immunology, which are within the skill of the art. Such techniques are explained fully in the literature. See e.g., Maniatis, Fitzsch & Sambrook, MOLECULAR CLONING; A LABORATORY MANUAL (1982); DNA CLONING, VOLUMES I AND II (D.N. Glover ed. 1985); OLIGONUCLEOTIDE SYNTHESIS (M.J. Gait ed, 1984); NUCLEIC ACID HYBRIDIZATION (B.D. Hames & S.J. Higgins eds. 1984); TRANSCRIPTION AND TRANSLATION (B.D. Hames & S.J. Higgins eds. 1984); ANIMAL CELL CULTURE (R.I. Freshney ed. 1986); IMMOBILIZED CELLS AND ENZYMES (IRL Press, 1986); B. Perbal, A PRACTICAL GUIDE TO MOLECULAR CLONING (1984); the series, METHODS IN ENZYMOLOGY (Academic Press, Inc.); GENE TRANSFER VECTORS FOR MAMMALIAN CELLS (J.H. Miller and M.P. Calos eds. 1987, Cold Spring Harbor Laboratory), Methods in Enzymology Vol. 154 and Vol. 155 (Wu and Grossman, and Wu, eds., respectively), Mayer and Walker, eds. (1987), IMMUNOCHEMICAL METHODS IN CELL AND MOLECULAR BIOLOGY (Academic Press, London), Scopes, (1987), PROTEIN PURIFICATION: PRINCIPLES AND PRACTICE, Second Edition (Springer-Verlag, N.Y.), and HANDBOOK OF EXPERIMENTAL IMMUNOLOGY, VOLUMES I-IV (D.M. Weir and C. C. Blackwell eds 1986). All patents, patent applications, and publications mentioned herein, both *supra* and *infra*, are hereby incorporated herein by reference.

The useful materials and processes of the present invention are made possible by the provision of a family of nucleotide sequences isolated from cDNA libraries which contain HCV cDNA sequences. These cDNA libr-

ies were derived from nucleic acid sequences present in the plasma of an HCV-infected chimpanzee. The construction of one of these libraries, the "c" library (ATCC No. 5 40394), was reported in EPO Pub. No. 318,216. Several of the clones containing HCV cDNA reported herein were obtained from the "c" library. Although other clones reported herein were obtained from other HCV cDNA libraries, the presence of clones containing the sequences in 10 the "c" library was confirmed. As discussed in EPO Pub. No. 318,216, the family of HCV cDNA sequences isolated from the "c" library are not of human or chimpanzee origin, and show no significant homology to sequences contained within the HBV genome.

15 The availability of the HCV cDNAs described herein permits the construction of polynucleotide probes which are reagents useful for detecting viral polynucleotides in biological samples, including donated blood. For example, from the sequences it is possible to 20 synthesize DNA oligomers of about 8-10 nucleotides, or larger, which are useful as hybridization probes to detect the presence of HCV RNA in, for example, donated blood, sera of subjects suspected of harboring the virus, or cell culture systems in which the virus is replicating. In 25 addition, the cDNA sequences also allow the design and production of HCV specific polypeptides which are useful as diagnostic reagents for the presence of antibodies raised during HCV infection. Antibodies to purified polypeptides derived from the cDNAs may also be used to 30 detect viral antigens in biological samples, including, for example, donated blood samples, sera from patients with NANBH, and in tissue culture systems being used for HCV replication. Moreover, the immunogenic polypeptides disclosed herein, which are encoded in portions of the ORF 35 of HCV cDNA shown in Fig. 17, are also useful for HCV

screening, diagnosis, and treatment, and for raising antibodies which are also useful for these purposes.

5 In addition, the novel cDNA sequences described herein enable further characterization of the HCV genome. Polynucleotide probes and primers derived from these sequences may be used to amplify sequences present in cDNA libraries, and/or to screen cDNA libraries for additional overlapping cDNA sequences, which, in turn, may be used to obtain more overlapping sequences. As indicated infra. and in EPO Pub. No. 318,216, the genome of HCV appears to be RNA comprised primarily of a large open reading frame (ORF) which encodes a large polyprotein.

15 The HCV cDNA sequences provided herein, the polypeptides derived from these sequences, and the immunogenic polypeptides described herein, as well as antibodies directed against these polypeptides are also useful in the isolation and identification of the blood-borne NABV (BB-NANBV) agent(s). For example, antibodies directed against HCV epitopes contained in polypeptides derived from the cDNAs may be used in processes based upon affinity chromatography to isolate the virus. Alternatively, the antibodies may be used to identify viral particles isolated by other techniques. The viral 20 antigens and the genomic material within the isolated viral particles may then be further characterized.

25 In addition to the above, the information provided infra allows the identification of additional HCV strains or isolates. The isolation and characterization 30 of the additional HCV strains or isolates may be accomplished by isolating the nucleic acids from body components which contain viral particles and/or viral RNA, creating cDNA libraries using polynucleotide probes based 35 on the HCV cDNA probes described infra., screening the libraries for clones containing HCV cDNA sequences described infra., and comparing the HCV cDNAs from the new

isolates with the cDNAs described infra. The polypeptides encoded therein, or in the viral genome, may be monitored for immunological cross-reactivity utilizing the 5 polypeptides and antibodies described supra. Strains or isolates which fit within the parameters of HCV, as described in the Definitions section, supra., are readily identifiable. Other methods for identifying HCV strains will be obvious to those of skill in the art, based upon 10 the information provided herein.

Isolation of the HCV cDNA Sequences

The novel HCV cDNA sequences described infra. extend the sequence of the cDNA to the HCV genome reported 15 in EPO Pub. No. 318,216. The sequences which are present in clones b114a, 18g, ag30a, CA205a, CA290a, CA216a, pi14a, CA167b, CA156e, CA84a, and CA59a lie upstream of the reported sequence, and when compiled, yield 20 nucleotides nos. -319 to 1348 of the composite HCV cDNA sequence. (The negative number on a nucleotide indicates its distance upstream of the nucleotide which starts the putative initiator MET codon.) The sequences which are present in clones b5a and 16jh lie downstream of the 25 reported sequence, and yield nucleotides nos. 8659 to 8866 of the composite sequence. The composite HCV cDNA sequence which includes the sequences in the aforementioned clones, is shown in Fig. 17.

The novel HCV cDNAs described herein were 30 isolated from a number of HCV cDNA libraries, including the "c" library present in lambda gt11 (ATCC No. 40394). The HCV cDNA libraries were constructed using pooled serum from a chimpanzee with chronic HCV infection and containing a high titer of the virus, i.e., at least 10^6 chimp 35 infectious doses/ml (CID/ml). The pooled serum was used to isolate viral particles; nucleic acids isolated from these particles was used as the template in the construc-

tion of cDNA libraries to the viral genome. The procedures for isolation of putative HCV particles and for constructing the "c" HCV cDNA library is described in EPO 5 Pub. No. 318,216. Other methods for constructing HCV cDNA libraries are known in the art, and some of these methods are described infra., in the Examples. Isolation of the sequences was by screening the libraries using synthetic polynucleotide probes, the sequences of which were derived 10 from the 5'-region and the 3'-region of the known HCV cDNA sequence. The description of the method to retrieve the cDNA sequences is mostly of historical interest. The resultant sequences (and their complements) are provided 15 herein, and the sequences, or any portion thereof, could be prepared using synthetic methods, or by a combination of synthetic methods with retrieval of partial sequences using methods similar to those described herein.

Preparation of Viral Polypeptides and Fragments

20 The availability of HCV cDNA sequences, or nucleotide sequences derived therefrom (including segments and modifications of the sequence), permits the construction of expression vectors encoding antigenically active regions of the polypeptide encoded in either strand. 25 These antigenically active regions may be derived from coat or envelope antigens or from core antigens, or from antigens which are non-structural including, for example, polynucleotide binding proteins, polynucleotide polymerase(s), and other viral proteins required for the 30 replication and/or assembly of the virus particle. Fragments encoding the desired polypeptides are derived from the cDNA clones using conventional restriction digestion or by synthetic methods, and are ligated into vectors which may, for example, contain portions of fusion 35 sequences such as beta-galactosidase or superoxide dismutase (SOD), preferably SOD. Methods and vectors

which are useful for the production of polypeptides which contain fusion sequences of SOD are described in European Patent Office Publication number 0196056, published 5 October 1, 1986. Vectors for the expression of fusion polypeptides of SOD and HCV polypeptides encoded in a number of HCV clones are described infra., in the Examples. Any desired portion of the HCV cDNA containing 10 an open reading frame, in either sense strand, can be obtained as a recombinant polypeptide, such as a mature or fusion protein; alternatively, a polypeptide encoded in the cDNA can be provided by chemical synthesis.

The DNA encoding the desired polypeptide, whether in fused or mature form, and whether or not 15 containing a signal sequence to permit secretion, may be ligated into expression vectors suitable for any convenient host. Both eukaryotic and prokaryotic host systems are presently used in forming recombinant 20 polypeptides, and a summary of some of the more common control systems and host cell lines is given infra. The polypeptide is then isolated from lysed cells or from the culture medium and purified to the extent needed for its intended use. Purification may be by techniques known in the art, for example, differential extraction, salt 25 fractionation, chromatography on ion exchange resins, affinity chromatography, centrifugation, and the like. See, for example, Methods in Enzymology for a variety of methods for purifying proteins. Such polypeptides can be 30 used as diagnostics, or those which give rise to neutralizing antibodies may be formulated into vaccines. Antibodies raised against these polypeptides can also be used as diagnostics, or for passive immunotherapy. In addition, as discussed infra., antibodies to these 35 polypeptides are useful for isolating and identifying HCV particles.

Preparation of Antigenic Polypeptides and Conjugation with Carrier

5 An antigenic region of a polypeptide is generally relatively small--typically 8 to 10 amino acids or less in length. Fragments of as few as 5 amino acids may characterize an antigenic region. These segments may correspond to regions of HCV antigen. Accordingly, using the 10 cDNAs of HCV as a basis, DNAs encoding short segments of HCV polypeptides can be expressed recombinantly either as fusion proteins, or as isolated polypeptides. In addition, short amino acid sequences can be conveniently obtained by chemical synthesis. In instances wherein the 15 synthesized polypeptide is correctly configured so as to provide the correct epitope, but is too small to be immunogenic, the polypeptide may be linked to a suitable carrier.

20 A number of techniques for obtaining such linkage are known in the art, including the formation of disulfide linkages using N-succinimidyl-3-(2-pyridyl-thio)propionate (SPDP) and succinimidyl 4-(N-maleimido-methyl)cyclohexane-1-carboxylate (SMCC) obtained from Pierce Company, Rockford, Illinois, (if the peptide lacks 25 a sulphydryl group, this can be provided by addition of a cysteine residue.) These reagents create a disulfide linkage between themselves and peptide cysteine residues on one protein and an amide linkage through the epsilon-amino on a lysine, or other free amino group in the other. A variety of such disulfide/amide-forming agents are 30 known. See, for example, Immun. Rev. (1982) 62:185. Other bifunctional coupling agents form a thioether rather than a disulfide linkage. Many of these thio-ether-forming agents are commercially available and include reactive esters of 6-maleimidocaproic acid, 2-bromoacetic 35 acid, 2-iodoacetic acid, 4-(N-maleimido-methyl)cyclohexane-1-carboxylic acid, and the like. The

carboxyl groups can be activated by combining them with succinimide or 1-hydroxyl-2-nitro-4-sulfonic acid, sodium salt. Additional methods of coupling antigens employs the 5 rotavirus/"binding peptide" system described in EPO Pub. No. 259,149, the disclosure of which is incorporated herein by reference. The foregoing list is not meant to be exhaustive, and modifications of the named compounds can clearly be used.

10 Any carrier may be used which does not, itself induce the production of antibodies harmful to the host. Suitable carriers are typically large, slowly metabolized macromolecules such as proteins; polysaccharides, such as latex functionalized sepharose, agarose, cellulose, cel- 15 lulose beads and the like; polymeric amino acids, such as polyglutamic acid, polylysine, and the like; amino acid copolymers; and inactive virus particles. Especially useful protein substrates are serum albumins, keyhole limpet hemocyanin, immunoglobulin molecules, thyroglobulin, 20 ovalbumin, tetanus toxoid, and other proteins well known to those skilled in the art.

25 In addition to full-length viral proteins, polypeptides comprising truncated HCV amino acid sequences encoding at least one viral epitope are useful immunological reagents. For example, polypeptides comprising such truncated sequences can be used as reagents in an immunoassay. These polypeptides also are candidate 30 subunit antigens in compositions for antiserum production or vaccines. While these truncated sequences can be produced by various known treatments of native viral protein, it is generally preferred to make synthetic or recombinant polypeptides comprising an HCV sequence. Polypeptides comprising these truncated HCV sequences can 35 be made up entirely of HCV sequences (one or more epitopes, either contiguous or noncontiguous), or HCV sequences and heterologous sequences in a fusion protein.

Useful heterologous sequences include sequences that provide for secretion from a recombinant host, enhance the immunological reactivity of the HCV epitope(s), or 5 facilitate the coupling of the polypeptide to an immunoassay support or a vaccine carrier. See, e.g., EPO Pub. No. 116,201; U.S. Pat. No. 4,722,840; EPO Pub. No. 259,149; U.S. Pat. No. 4,629,783, the disclosures of 10 which are incorporated herein by reference.

The size of polypeptides comprising the truncated HCV sequences can vary widely, the minimum size being a sequence of sufficient size to provide an HCV epitope, while the maximum size is not critical. For 15 convenience, the maximum size usually is not substantially greater than that required to provide the desired HCV epitopes and function(s) of the heterologous sequence, if any. Typically, the truncated HCV amino acid sequence will range from about 5 to about 100 amino acids in 20 length. More typically, however, the HCV sequence will be a maximum of about 50 amino acids in length, preferably a maximum of about 30 amino acids. It is usually desirable to select HCV sequences of at least about 10, 12 or 15 25 amino acids, up to a maximum of about 20 or 25 amino acids.

Truncated HCV amino acid sequences comprising epitopes can be identified in a number of ways. For example, the entire viral protein sequence can be screened 30 by preparing a series of short peptides that together span the entire protein sequence. An example of antigenic screening of the regions of the HCV polyprotein is shown infra. In addition, by starting with, for example, 100mer polypeptides, it would be routine to test each polypeptide for the presence of epitope(s) showing a desired reactivity, and then testing progressively smaller and overlapping 35 fragments from an identified 100mer to map the epitope of interest. Screening such peptides in an

immunoassay is within the skill of the art. It is also known to carry out a computer analysis of a protein sequence to identify potential epitopes, and then prepare 5 oligopeptides comprising the identified regions for screening. Such a computer analysis of the HCV amino acid sequence is shown in Fig. 20, where the hydrophilic/ hydrophobic character is displayed above the antigen index. The amino acids are numbered from the starting MET 10 (position 1) as shown in Fig. 17. It is appreciated by those of skill in the art that such computer analysis of antigenicity does not always identify an epitope that actually exists, and can also incorrectly identify a 15 region of the protein as containing an epitope.

Examples of HCV amino acid sequences that may be useful, which are expressed from expression vectors comprised of clones 5-1-1, 81, CA74a, 35f, 279a, C36, C33b, CA290a, C8f, C12f, 14c, 15e, C25c, C33c, C33f, 33g, 20 C39c, C40b, CA167b are described infra. Other examples of HCV amino acid sequences that may be useful as described herein are set forth below. It is to be understood that these peptides do not necessarily precisely map one epitope, and may also contain HCV sequence that is not 25 immunogenic. These non-immunogenic portions of the sequence can be defined as described above using conventional techniques and deleted from the described sequences. Further, additional truncated HCV amino acid sequences that comprise an epitope or are immunogenic can 30 be identified as described above. The following sequences are given by amino acid number (i.e., "AA_n") where n is the amino acid number as shown in Fig. 17:

35 AA1-AA25; AA1-AA50; AA1-AA84; AA9-AA177; AA1-AA10; AA5-AA20; AA20-AA25; AA35-AA45; AA50-AA100; AA40-AA90; AA45-AA65; AA65-AA75; AA80-90; AA99-AA120; AA95-AA110; AA105-AA120; AA100-AA150; AA150-AA200; AA155-AA170; AA190-AA210; AA200-AA250; AA220-AA240;

AA245-AA265; AA250-AA300; AA290-AA330; AA290-305;
AA300-AA350; AA310-AA330; AA350-AA400; AA380-AA395;
AA405-AA495; AA400-AA450; AA405-AA415; AA415-AA425;
AA425-AA435; AA437-AA582; AA450-AA500; AA440-AA460;
AA460-AA470; AA475-AA495; AA500-AA550; AA511-AA690;
AA515-AA550; AA550-AA600; AA550-AA625; AA575-AA605;
AA585-AA600; AA600-AA650; AA600-AA625; AA635-AA665;
AA650-AA700; AA645-AA680; AA700-AA750; AA700-AA725;
AA700-AA750; AA725-AA775; AA770-AA790; AA750-AA800;
AA800-AA815; AA825-AA850; AA850-AA875; AA800-AA850;
AA920-AA990; AA850-AA900; AA920-AA945; AA940-AA965;
AA970-AA990; AA950-AA1000; AA1000-AA1060;
AA1000-AA1025; AA1000-AA1050; AA1025-AA1040;
AA1040-AA1055; AA1075-AA1175; AA1050-AA1200;
AA1070-AA1100; AA1100-AA1130; AA1140-AA1165;
AA1192-AA1457; AA1195-AA1250; AA1200-AA1225;
AA1225-AA1250; AA1250-AA1300; AA1260-AA1310;
AA1260-AA1280; AA1266-AA1428; AA1300-AA1350;
AA1290-AA1310; AA1310-AA1340; AA1345-AA1405;
AA1345-AA1365; AA1350-AA1400; AA1365-AA1380;
AA1380-AA1405; AA1400-AA1450; AA1450-AA1500;
AA1460-AA1475; AA1475-AA1515; AA1475-AA1500;
AA1500-AA1550; AA1500-AA1515; AA1515-AA1550;
AA1550-AA1600; AA1545-AA1560; AA1569-AA1931;
AA1570-AA1590; AA1595-AA1610; AA1590-AA1650;
AA1610-AA1645; AA1650-AA1690; AA1685-AA1770;
AA1689-AA1805; AA1690-AA1720; AA1694-AA1735;
AA1720-AA1745; AA1745-AA1770; AA1750-AA1800;
AA1775-AA1810; AA1795-AA1850; AA1850-AA1900;
AA1900-AA1950; AA1900-AA1920; AA1916-AA2021;
AA1920-AA1940; AA1949-AA2124; AA1950-AA2000;
AA1950-AA1985; AA1980-AA2000; AA2000-AA2050;
AA2005-AA2025; AA2020-AA2045; AA2045-AA2100;
AA2045-AA2070; AA2054-AA2223; AA2070-AA2100;
AA2100-AA2150; AA2150-AA2200; AA2200-AA2250;
AA2200-AA2325; AA2250-AA2330; AA2255-AA2270;
AA2265-AA2280; AA2280-AA2290; AA2287-AA2385;
AA2300-AA2350; AA2290-AA2310; AA2310-AA2330;
AA2330-AA2350; AA2350-AA2400; AA2348-AA2464;
AA2345-AA2415; AA2345-AA2375; AA2370-AA2410;
AA2371-AA2502; AA2400-AA2450; AA2400-AA2425;
AA2415-AA2450; AA2445-AA2500; AA2445-AA2475;
AA2470-AA2490; AA2500-AA2550; AA2505-AA2540;
AA2535-AA2560; AA2550-AA2600; AA2560-AA2580;
AA2600-AA2650; AA2605-AA2620; AA2620-AA2650;
AA2640-AA2660; AA2650-AA2700; AA2655-AA2670;
AA2670-AA2700; AA2700-AA2750; AA2740-AA2760;
AA2750-AA2800; AA2755-AA2780;
AA2780-AA2830; AA2785-AA2810; AA2796-AA2886;
AA2810-AA2825; AA2800-AA2850; AA2850-AA2900;
AA2850-AA2865; AA2885-AA2905; AA2900-AA2950;

AA2910-AA2930; AA2925-AA2950; AA2945-end(C' terminal).

5 The above HCV amino acid sequences can be prepared as discrete peptides or incorporated into a larger polypeptide, and may find use as described herein. Additional polypeptides comprising truncated HCV sequences are described in the examples.

10 The observed relationship of the putative polyproteins of HCV and the Flaviviruses allows some prediction of the putative domains of the HCV "non-structural" (NS) proteins. The locations of the individual NS proteins in the putative Flavivirus precursor polyprotein are fairly well-known. Moreover, these 15 also coincide with observed gross fluctuations in the hydrophobicity profile of the polyprotein. It is established that NS5 of Flaviviruses encodes the virion polymerase, and that NS1 corresponds with a complement fixation antigen which has been shown to be an effective 20 vaccine in animals. Recently, it has been shown that a flaviviral protease function resides in NS3. Due to the observed similarities between HCV and the Flaviviruses, described infra., deductions concerning the approximate 25 locations of the corresponding protein domains and functions in the HCV polyprotein are possible. The expression of polypeptides containing these domains in a variety of recombinant host cells, including, for example, bacteria, yeast, insect, and vertebrate cells, should give rise to 30 important immunological reagents which can be used for diagnosis, detection, and vaccines.

35 Although the non-structural protein regions of the putative polyproteins of the HCV isolate described herein and of Flaviviruses appear to have some similarity, there is less similarity between the putative structural regions which are towards the N-terminus. In this region, there is a greater divergence in sequence, and in addi-

tion, the hydrophobic profile of the two regions show less similarity. This "divergence" begins in the N-terminal region of the putative NS1 domain in HCV, and extends to the presumed N-terminus. Nevertheless, it may still be possible to predict the approximate locations of the putative nucleocapsid (N-terminal basic domain) and E (generally hydrophobic) domains within the HCV polyprotein. In the Examples the predictions are based on the changes observed in the hydrophobic profile of the HCV polyprotein, and on a knowledge of the location and character of the flaviviral proteins. From these predictions it may be possible to identify approximate regions of the HCV polyprotein that could correspond with useful immunological reagents. For example, the E and NS1 proteins of Flaviviruses are known to have efficacy as protective vaccines. These regions, as well as some which are shown to be antigenic in the HCV isolate described herein, for example those within putative NS3, C, and NS5, etc., should also provide diagnostic reagents. Moreover, the location and expression of viral-encoded enzymes may also allow the evaluation of anti-viral enzyme inhibitors, i.e., for example, inhibitors which prevent enzyme activity by virtue of an interaction with the enzyme itself, or substances which may prevent expression of the enzyme, (for example, anti-sense RNA, or other drugs which interfere with expression).

30 Preparation of Hybrid Particle Immunogens Containing HCV Epitopes

35 The immunogenicity of the epitopes of HCV may also be enhanced by preparing them in mammalian or yeast systems fused with or assembled with particle-forming proteins such as, for example, that associated with hepatitis B surface antigen. Constructs wherein the NANBv epitope is linked directly to the particle-forming protein

5 coding sequences produce hybrids which are immunogenic with respect to the HCV epitope. In addition, all of the vectors prepared include epitopes specific to HBV, having various degrees of immunogenicity, such as, for example, the pre-S peptide. Thus, particles constructed from particle forming protein which include HCV sequences are immunogenic with respect to HCV and HBV.

10 Hepatitis surface antigen (HBSAg) has been shown to be formed and assembled into particles in S. cerevisiae (Valenzuela et al. (1982)), as well as in, for example, mammalian cells (Valenzuela, P., et al. (1984)). The formation of such particles has been shown to enhance the immunogenicity of the monomer subunit. The constructs may 15 also include the immunodominant epitope of HBSAg, comprising the 55 amino acids of the presurface (pre-S) region. Neurath et al. (1984). Constructs of the pre-S-HBSAg particle expressible in yeast are disclosed in EPO 174,444, published March 19, 1986; hybrids including 20 heterologous viral sequences for yeast expression are disclosed in EPO 175,261, published March 26, 1986. These constructs may also be expressed in mammalian cells such as Chinese hamster ovary (CHO) cells using an SV40-dihydrofolate reductase vector (Michelle et al. (1984)).

25 In addition, portions of the particle-forming protein coding sequence may be replaced with codons encoding an HCV epitope. In this replacement, regions which are not required to mediate the aggregation of the units 30 to form immunogenic particles in yeast or mammals can be deleted, thus eliminating additional HBV antigenic sites from competition with the HCV epitope.

Preparation of Vaccines

35 Vaccines may be prepared from one or more immunogenic polypeptides derived from HCV cDNA, including the cDNA sequences described in the Examples. The

observed homology between HCV and Flaviviruses provides information concerning the polypeptides which may be most effective as vaccines, as well as the regions of the genome in which they are encoded. The general structure of the Flavivirus genome is discussed in Rice et al (1986). The flavivirus genomic RNA is believed to be the only virus-specific mRNA species, and it is translated into the three viral structural proteins, i.e., C, M, and E, as well as two large nonstructural proteins, NS4 and NS5, and a complex set of smaller nonstructural proteins. It is known that major neutralizing epitopes for Flaviviruses reside in the E (envelope) protein (Roehrig (1986)). Thus, vaccines may be comprised of recombinant polypeptides containing epitopes of HCV E. These polypeptides may be expressed in bacteria, yeast, or mammalian cells, or alternatively may be isolated from viral preparations. It is also anticipated that the other structural proteins may also contain epitopes which give rise to protective anti-HCV antibodies. Thus, polypeptides containing the epitopes of E, C, and M may also be used, whether singly or in combination, in HCV vaccines.

In addition to the above, it has been shown that immunization with NS1 (nonstructural protein 1), results in protection against yellow fever (Schlesinger et al (1986)). This is true even though the immunization does not give rise to neutralizing antibodies. Thus, particularly since this protein appears to be highly conserved among Flaviviruses, it is likely that HCV NS1 will also be protective against HCV infection. Moreover, it also shows that nonstructural proteins may provide protection against viral pathogenicity, even if they do not cause the production of neutralizing antibodies.

The information provided in the Examples concerning the immunogenicity of the polypeptides

expressed from cloned HCV cDNAs which span the various regions of the HCV ORF also allows predictions concerning their use in vaccines.

5 In view of the above, multivalent vaccines against HCV may be comprised of one or more epitopes from one or more structural proteins, and/or one or more epitopes from one or more nonstructural proteins. These 10 vaccines may be comprised of, for example, recombinant HCV polypeptides and/or polypeptides isolated from the virions. In particular, vaccines are contemplated comprising one or more of the following HCV proteins, or subunit antigens derived therefrom: E, NS1, C, NS2, NS3, 15 NS4 and NS5. Particularly preferred are vaccines comprising E and/or NS1, or subunits thereof.

15 The preparation of vaccines which contain an immunogenic polypeptide(s) as active ingredients, is known to one skilled in the art. Typically, such vaccines are prepared as injectables, either as liquid solutions or suspensions; solid forms suitable for solution in, or suspension in, liquid prior to injection may also be prepared. The preparation may also be emulsified, or the protein encapsulated in liposomes. The active immunogenic 20 ingredients are often mixed with excipients which are pharmaceutically acceptable and compatible with the active ingredient. Suitable excipients are, for example, water, saline, dextrose, glycerol, ethanol, or the like and combinations thereof. In addition, if desired, the vaccine 25 may contain minor amounts of auxiliary substances such as wetting or emulsifying agents, pH buffering agents, and/or adjuvants which enhance the effectiveness of the vaccine. Examples of adjuvants which may be effective include but are not limited to: aluminum hydroxide, 30 N-acetyl-muramyl-L-threonyl-D-isoglutamine (thr-MDP), N-acetyl-nor-muramyl-L-alanyl-D-isoglutamine (CGP 11637, 35 referred to as nor-MDP), N-acetylmuramyl-L-alanyl-D-

5 isoglutaminyl-L-alanine-2-(1'-2'-dipalmitoyl-sn-glycero-3-hydroxyphosphoryloxy)-ethylamine (CGP 19835A, referred to as MTP-PE), and RIBI, which contains three components extracted from bacteria, monophosphoryl lipid A, trehalose dimycolate and cell wall skeleton (MPL+TDM+CWS) in a 2% squalene/Tween 80 emulsion. The effectiveness of an adjuvant may be determined by measuring the amount of 10 antibodies directed against an immunogenic polypeptide containing an HCV antigenic sequence resulting from administration of this polypeptide in vaccines which are also comprised of the various adjuvants.

15 The vaccines are conventionally administered parenterally, by injection, for example, either subcutaneously or intramuscularly. Additional formulations which are suitable for other modes of administration include suppositories and, in some cases, oral formulations. For 20 suppositories, traditional binders and carriers may include, for example, polyalkylene glycols or triglycerides; such suppositories may be formed from mixtures containing the active ingredient in the range of 0.5% to 10%, preferably 1%-2%. Oral formulations include such normally employed excipients as, for example, 25 pharmaceutical grades of mannitol, lactose, starch, magnesium stearate, sodium saccharine, cellulose, magnesium carbonate, and the like. These compositions take the form of solutions, suspensions, tablets, pills, capsules, sustained release formulations or powders and 30 contain 10%-95% of active ingredient, preferably 25%-70%.

35 The proteins may be formulated into the vaccine as neutral or salt forms. Pharmaceutically acceptable salts include the acid addition salts (formed with free amino groups of the peptide) and which are formed with inorganic acids such as, for example, hydrochloric or phosphoric acids, or such organic acids such as acetic, oxalic, tartaric, maleic, and the like. Salts formed with

the free carboxyl groups may also be derived from in-
organic bases such as, for example, sodium, potassium,
5 ammonium, calcium, or ferric hydroxides, and such organic
bases as isopropylamine, trimethylamine, 2-ethylamino
ethanol, histidine, procaine, and the like.

Dosage and Administration of Vaccines

10 The vaccines are administered in a manner
compatible with the dosage formulation, and in such amount
as will be prophylactically and/or therapeutically effec-
tive. The quantity to be administered, which is generally
in the range of 5 micrograms to 250 micrograms of antigen
15 per dose, depends on the subject to be treated, capacity
of the subject's immune system to synthesize antibodies,
and the degree of protection desired. Precise amounts of
active ingredient required to be administered may depend
on the judgment of the practitioner and may be peculiar to
20 each subject.

25 The vaccine may be given in a single dose
schedule, or preferably in a multiple dose schedule. A
multiple dose schedule is one in which a primary course of
vaccination may be with 1-10 separate doses, followed by
other doses given at subsequent time intervals required to
maintain and or reinforce the immune response, for
example, at 1-4 months for a second dose, and if needed, a
subsequent dose(s) after several months. The dosage
30 regimen will also, at least in part, be determined by the
need of the individual and be dependent upon the judgment
of the practitioner.

35 In addition, the vaccine containing the im-
munogenic HCV antigen(s) may be administered in conjunc-
tion with other immunoregulatory agents, for example, im-
mune globulins.

Preparation of Antibodies Against HCV Epitopes

The immunogenic polypeptides prepared as described above are used to produce antibodies, both 5 polyclonal and monoclonal. If polyclonal antibodies are desired, a selected mammal (e.g., mouse, rabbit, goat, horse, etc.) is immunized with an immunogenic polypeptide bearing an HCV epitope(s). Serum from the immunized 10 animal is collected and treated according to known procedures. If serum containing polyclonal antibodies to an HCV epitope contains antibodies to other antigens, the polyclonal antibodies can be purified by immunoaffinity chromatography. Techniques for producing and processing 15 polyclonal antisera are known in the art, see for example, Mayer and Walker (1987).

Alternatively, polyclonal antibodies may be isolated from a mammal which has been previously infected with HCV. An example of a method for purifying antibodies 20 to HCV epitopes from serum from an infected individual, based upon affinity chromatography and utilizing a fusion polypeptide of SOD and a polypeptide encoded within cDNA clone 5-1-1, is presented in EPO Pub. No. 318,216.

Monoclonal antibodies directed against HCV 25 epitopes can also be readily produced by one skilled in the art. The general methodology for making monoclonal antibodies by hybridomas is well known. Immortal antibody-producing cell lines can be created by cell fusion, and also by other techniques such as direct transformation 30 of B lymphocytes with oncogenic DNA, or transfection with Epstein-Barr virus. See, e.g., M. Schreier et al. (1980); Hammerling et al. (1981); Kennett et al. (1980); see also, U.S. Patent Nos. 4,341,761; 4,399,121; 4,427,783; 4,444,887; 4,466,917; 4,472,500; 4,491,632; and 4,493,890. Panels of monoclonal antibodies 35 produced against HCV epitopes can be screened for various properties; i.e., for isotype, epitope affinity, etc.

5 Antibodies, both monoclonal and polyclonal, which are directed against HCV epitopes are particularly useful in diagnosis, and those which are neutralizing are useful in passive immunotherapy. Monoclonal antibodies, in particular, may be used to raise anti-idiotype antibodies.

10 Anti-idiotype antibodies are immunoglobulins which carry an "internal image" of the antigen of the infectious agent against which protection is desired. See, for example, Nisonoff, A., et al. (1981) and Dreesman et al. (1985).

15 Techniques for raising anti-idiotype antibodies are known in the art. See, for example, Grzych (1985), MacNamara et al. (1984), and Uytdehaag et al. (1985). These anti-idiotype antibodies may also be useful for treatment and/or diagnosis of NANBH, as well as for an elucidation of the immunogenic regions of HCV antigens.

20 It would also be recognized by one of ordinary skill in the art that a variety of types of antibodies directed against HCV epitopes may be produced. As used herein, the term "antibody" refers to a polypeptide or group of polypeptides which are comprised of at least one antibody combining site. An "antibody combining site" or "binding domain" is formed from the folding of variable domains of an antibody molecule(s) to form three-dimensional binding spaces with an internal surface shape and charge distribution complementary to the features of an epitope of an antigen, which allows an immunological reaction with the antigen. An antibody combining site may be formed from a heavy and/or a light chain domain (VH and VL, respectively), which form hypervariable loops which contribute to antigen binding. The term "antibody" includes, for example, vertebrate antibodies, hybrid antibodies, chimeric antibodies, altered antibodies, univalent

antibodies, the Fab proteins, and single domain antibodies.

5 A "single domain antibody" (dAb) is an antibody which is comprised of an VH domain, which reacts immunologically with a designated antigen. A dAb does not contain a VL domain, but may contain other antigen binding domains known to exist in antibodies, for example, the 10 kappa and lambda domains. Methods for preparing dAb's are known in the art. See, for example, Ward et al. (1989).

15 Antibodies may also be comprised of VH and VL domains, as well as other known antigen binding domains. Examples of these types of antibodies and methods for their preparation are known in the art (see, e.g., U.S. Patent No. 4,816,467, which is incorporated herein by reference), and include the following. For example, "vertebrate antibodies" refers to antibodies which are 20 tetramers or aggregates thereof, comprising light and heavy chains which are usually aggregated in a "Y" configuration and which may or may not have covalent linkages between the chains. In vertebrate antibodies, the amino acid sequences of all the chains of a particular antibody are homologous with the chains found in one antibody produced by the lymphocyte which produces that antibody in situ, or in vitro (for example, in hybridomas). 25 Vertebrate antibodies typically include native antibodies, for example, purified polyclonal antibodies and monoclonal antibodies. Examples of the methods for the preparation of these antibodies are described infra.

30 "Hybrid antibodies" are antibodies wherein one pair of heavy and light chains is homologous to those in a first antibody, while the other pair of heavy and light chains is homologous to those in a different second antibody. Typically, each of these two pairs will bind different epitopes, particularly on different antigens. This 35 results in the property of "divalence", i.e., the ability

to bind two antigens simultaneously. Such hybrids may also be formed using chimeric chains, as set forth below.

5 "Chimeric antibodies", are antibodies in which the heavy and/or light chains are fusion proteins. Typically the constant domain of the chains is from one particular species and/or class, and the variable domains are from a different species and/or class. Also included 10 is any antibody in which either or both of the heavy or light chains are composed of combinations of sequences mimicking the sequences in antibodies of different sources, whether these sources be differing classes, or different species of origin, and whether or not the fusion point is at the variable/constant boundary. Thus, it is 15 possible to produce antibodies in which neither the constant nor the variable region mimic known antibody sequences. It then becomes possible, for example, to construct antibodies whose variable region has a higher specific affinity for a particular antigen, or whose 20 constant region can elicit enhanced complement fixation, or to make other improvements in properties possessed by a particular constant region.

Another example is "altered antibodies", which 25 refers to antibodies in which the naturally occurring amino acid sequence in a vertebrate antibody has been varied. Utilizing recombinant DNA techniques, antibodies can be redesigned to obtain desired characteristics. The possible variations are many, and range from the changing 30 of one or more amino acids to the complete redesign of a region, for example, the constant region. Changes in the constant region, in general, to attain desired cellular process characteristics, e.g., changes in complement fixation, interaction with membranes, and other effector 35 functions. Changes in the variable region may be made to alter antigen binding characteristics. The antibody may also be engineered to aid the specific delivery of a

5 molecule or substance to a specific cell or tissue site. The desired alterations may be made by known techniques in molecular biology, e.g., recombinant techniques, site directed mutagenesis, etc.

10 Yet another example are "univalent antibodies", which are aggregates comprised of a heavy chain/light chain dimer bound to the Fc (i.e., constant) region of a second heavy chain. This type of antibody escapes antigenic modulation. See, e.g., Glennie et al. (1982).

15 Included also within the definition of antibodies are "Fab" fragments of antibodies. The "Fab" region refers to those portions of the heavy and light chains which are roughly equivalent, or analogous, to the sequences which comprise the branch portion of the heavy and light chains, and which have been shown to exhibit immunological binding to a specified antigen, but which lack the effector Fc portion. "Fab" includes aggregates of one heavy and one light chain (commonly known as Fab'), as well as tetramers containing the 2H and 2L chains (referred to as $F(ab)_2$), which are capable of selectively reacting with a designated antigen or antigen family. "Fab" antibodies may be divided into subsets analogous to those described above, i.e., "vertebrate Fab", "hybrid Fab", "chimeric Fab", and "altered Fab". Methods of producing "Fab" fragments of antibodies are known within the art and include, for example, proteolysis, and synthesis by recombinant techniques.

30 **II.H. Diagnostic Oligonucleotide Probes and Kits**

35 Using the disclosed portions of the isolated HCV cDNAs as a basis, oligomers of approximately 8 nucleotides or more can be prepared, either by excision or synthetically, which hybridize with the HCV genome and are useful in identification of the viral agent(s), further characterization of the viral genome(s), as well as in

5 detection of the virus(es) in diseased individuals. The probes for HCV polynucleotides (natural or derived) are a length which allows the detection of unique viral
10 sequences by hybridization. While 6-8 nucleotides may be a workable length, sequences of 10-12 nucleotides are preferred, and about 20 nucleotides appears optimal. Preferably, these sequences will derive from regions which lack heterogeneity. These probes can be prepared using routine methods, including automated oligonucleotide synthetic methods. Among useful probes, for example, are those derived from the newly isolated clones disclosed herein, as well as the various oligomers useful in probing
15 cDNA libraries, set forth below. A complement to any unique portion of the HCV genome will be satisfactory. For use as probes, complete complementarity is desirable, though it may be unnecessary as the length of the fragment is increased.

20 For use of such probes as diagnostics, the biological sample to be analyzed, such as blood or serum, may be treated, if desired, to extract the nucleic acids contained therein. The resulting nucleic acid from the sample may be subjected to gel electrophoresis or other size separation techniques; alternatively, the nucleic acid sample may be dot blotted without size separation.
25 The probes are then labeled. Suitable labels, and methods for labeling probes are known in the art, and include, for example, radioactive labels incorporated by nick translation or kinasing, biotin, fluorescent probes, and chemiluminescent probes. The nucleic acids extracted from the sample are then treated with the labeled probe under hybridization conditions of suitable stringencies, and polynucleotide duplexes containing the probe are detected.

30 35 The probes can be made completely complementary to the HCV genome. Therefore, usually high stringency conditions are desirable in order to prevent false

positives. However, conditions of high stringency should only be used if the probes are complementary to regions of the viral genome which lack heterogeneity. The stringency of hybridization is determined by a number of factors during hybridization and during the washing procedure, including temperature, ionic strength, length of time, and concentration of formamide. These factors are outlined in, for example, Maniatis, T. (1982).

10 Generally, it is expected that the HCV genome sequences will be present in serum of infected individuals at relatively low levels, i.e., at approximately 10^2 - 10^3 chimp infectious doses (CID) per ml. This level may require that amplification techniques be used in

15 hybridization assays. Such techniques are known in the art. For example, the Enzo Biochemical Corporation "Bio-Bridge" system uses terminal deoxynucleotide transferase to add unmodified 3'-poly-dT-tails to a DNA probe. The poly dT-tailed probe is hybridized to the target

20 nucleotide sequence, and then to a biotin-modified poly-A. PCT application 84/03520 and EPA124221 describe a DNA hybridization assay in which: (1) analyte is annealed to a single-stranded DNA probe that is complementary to an enzyme-labeled oligonucleotide; and (2) the resulting

25 tailed duplex is hybridized to an enzyme-labeled oligonucleotide. EPA 204510 describes a DNA hybridization assay in which analyte DNA is contacted with a probe that has a tail, such as a poly-dT tail, an amplifier strand that has a sequence that hybridizes to the tail of the

30 probe, such as a poly-A sequence, and which is capable of binding a plurality of labeled strands. A particularly desirable technique may first involve amplification of the target HCV sequences in sera approximately 10,000 fold, i.e., to approximately 10^6 sequences/ml. This may be accomplished, for example, by the polymerase chain reactions (PCR) technique described which is by Saiki et al. (1986),

by Mullis, U.S. Patent No. 4,683,195, and by Mullis et al. U.S. Patent No. 4,683,202. The amplified sequence(s) may then be detected using a hybridization assay which is 5 described in EP 317,077, published May 24, 1989. These hybridization assays, which should detect sequences at the level of 10^6 /ml, utilize nucleic acid multimers which bind to single-stranded analyte nucleic acid, and which also bind to a multiplicity of single-stranded labeled 10 oligonucleotides. A suitable solution phase sandwich assay which may be used with labeled polynucleotide probes, and the methods for the preparation of probes is described in EPO 225,807, published June 16, 1987.

15 The probes can be packaged into diagnostic kits. Diagnostic kits include the probe DNA, which may be labeled; alternatively, the probe DNA may be unlabeled and the ingredients for labeling may be included in the kit in separate containers. The kit may also contain other suitably packaged reagents and materials needed for the 20 particular hybridization protocol, for example, standards, as well as instructions for conducting the test.

Immunoassay and Diagnostic Kits

25 Both the polypeptides which react immuno- logically with serum containing HCV antibodies, for example, those detected by the antigenic screening method described infra. in the Examples, as well those derived from or encoded within the isolated clones described in 30 the Examples, and composites thereof, and the antibodies raised against the HCV specific epitopes in these polypeptides, are useful in immunoassays to detect presence of HCV antibodies, or the presence of the virus and/ or viral antigens, in biological samples. Design of the 35 immunoassays is subject to a great deal of variation, and a variety of these are known in the art. For example, the immunoassay may utilize one viral epitope; alternatively,

the immunoassay may use a combination of viral epitopes derived from these sources; these epitopes may be derived from the same or from different viral polypeptides, and 5 may be in separate recombinant or natural polypeptides, or together in the same recombinant polypeptides. It may use, for example, a monoclonal antibody directed towards a viral epitope(s), a combination of monoclonal antibodies directed towards epitopes of one viral antigen, monoclonal 10 antibodies directed towards epitopes of different viral antigens, polyclonal antibodies directed towards the same viral antigen, or polyclonal antibodies directed towards different viral antigens. Protocols may be based, for example, upon competition, or direct reaction, or sandwich 15 type assays. Protocols may also, for example, use solid supports, or may be by immunoprecipitation. Most assays involve the use of labeled antibody or polypeptide; the labels may be, for example, fluorescent, chemiluminescent, radioactive, or dye molecules. Assays which amplify the 20 signals from the probe are also known; examples of which are assays which utilize biotin and avidin, and enzyme-labeled and mediated immunoassays, such as ELISA assays.

Some of the antigenic regions of the putative 25 polyprotein have been mapped and identified by screening the antigenicity of bacterial expression products of HCV cDNAs which encode portions of the polyprotein. See the Examples. Other antigenic regions of HCV may be detected by expressing the portions of the HCV cDNAs in other 30 expression systems, including yeast systems and cellular systems derived from insects and vertebrates. In addition, studies giving rise to an antigenicity index and hydrophobicity/hydrophilicity profile give rise to information concerning the probability of a region's 35 antigenicity.

The studies on antigenic mapping by expression of HCV cDNAs showed that a number of clones containing

these cDNAs expressed polypeptides which were immunologically reactive with serum from individuals with NANBH. No single polypeptide was immunologically reactive with all sera. Five of these polypeptides were very immunogenic in that antibodies to the HCV epitopes in these polypeptides were detected in many different patient sera, although the overlap in detection was not complete. Thus, the results on the immunogenicity of the polypeptides encoded in the various clones suggest that efficient detection systems may include the use of panels of epitopes. The epitopes in the panel may be constructed into one or multiple polypeptides.

Kits suitable for immunodiagnosis and containing the appropriate labeled reagents are constructed by packaging the appropriate materials, including the polypeptides of the invention containing HCV epitopes or antibodies directed against HCV epitopes in suitable containers, along with the remaining reagents and materials required for the conduct of the assay, as well as a suitable set of assay instructions.

Further Characterization of the HCV Genome, Virions, and Viral Antigens Using Probes Derived From cDNA to the Viral Genome

The HCV cDNA sequence information in the newly isolated clones described in the Examples may be used to gain further information on the sequence of the HCV genome, and for identification and isolation of the HCV agent, and thus will aid in its characterization including the nature of the genome, the structure of the viral particle, and the nature of the antigens of which it is composed. This information, in turn, can lead to additional polynucleotide probes, polypeptides derived from the HCV genome, and antibodies directed against HCV.

epitopes which would be useful for the diagnosis and/or treatment of HCV caused NANBH.

5 The cDNA sequence information in the above-mentioned clones is useful for the design of probes for the isolation of additional cDNA sequences which are derived from as yet undefined regions of the HCV genome(s) from which the cDNAs in clones described herein and in EP 0,316,218 are derived. For example, labeled probes
10 containing a sequence of approximately 8 or more nucleotides, and preferably 20 or more nucleotides, which are derived from regions close to the 5'-termini or 3'-termini of the composite HCV cDNA sequence shown in Fig. 17 may be used to isolate overlapping cDNA sequences from HCV cDNA
15 libraries. Alternatively, characterization of the genomic segments could be from the viral genome(s) isolated from purified HCV particles. Methods for purifying HCV particles and for detecting them during the purification procedure are described herein, infra. Procedures for
20 isolating polynucleotide genomes from viral particles are known in the art, and one procedure which may be used is that described in EP 0,218,316. The isolated genomic segments could then be cloned and sequenced. An example of
25 this technique, which utilizes amplification of the sequences to be cloned, is provided infra., and yielded clone 16jh.

Methods for constructing cDNA libraries are known in the art, and are discussed supra and infra; a
30 method for the construction of HCV cDNA libraries in lambda-gt11 is discussed in EPO Pub. No. 318,216. However, cDNA libraries which are useful for screening with nucleic acid probes may also be constructed in other vectors known in the art, for example, lambda-gt10 (Huynh
35 et al. (1985)).

Screening for Anti-Viral Agents for HCV

5 The availability of cell culture and animal model systems for HCV makes it possible to screen for anti-viral agents which inhibit HCV replication, and particularly for those agents which preferentially allow cell growth and multiplication while inhibiting viral replication. These screening methods are known by those of skill in the art. Generally, the anti-viral agents are 10 tested at a variety of concentrations, for their effect on preventing viral replication in cell culture systems which support viral replication, and then for an inhibition of infectivity or of viral pathogenicity (and a low level of toxicity) in an animal model system.

15 The methods and compositions provided herein for detecting HCV antigens and HCV polynucleotides are useful for screening of anti-viral agents in that they provide an alternative, and perhaps more sensitive means, for detecting the agent's effect on viral replication than the cell 20 plaque assay or ID₅₀ assay. For example, the HCV-polynucleotide probes described herein may be used to quantitate the amount of viral nucleic acid produced in a cell culture. This could be accomplished, for example, by hybridization or competition hybridization of the infected 25 cell nucleic acids with a labeled HCV-polynucleotide probe. For example, also, anti-HCV antibodies may be used to identify and quantitate HCV antigen(s) in the cell culture utilizing the immunoassays described herein. In addition, since it may be desirable to quantitate HCV 30 antigens in the infected cell culture by a competition assay, the polypeptides encoded within the HCV cDNAs described herein are useful in these competition assays. Generally, a recombinant HCV polypeptide derived from the 35 HCV cDNA would be labeled, and the inhibition of binding of this labeled polypeptide to an HCV polypeptide due to the antigen produced in the cell culture system would be

monitored. Moreover, these techniques are particularly useful in cases where the HCV may be able to replicate in a cell line without causing cell death.

5 The anti-viral agents which may be tested for efficacy by these methods are known in the art, and include, for example, those which interact with virion components and/or cellular components which are necessary for the binding and/or replication of the virus. Typical 10 anti-viral agents may include, for example, inhibitors of virion polymerase and/or protease(s) necessary for cleavage of the precursor polypeptides. Other anti-viral agents may include those which act with nucleic acids to prevent viral replication, for example, anti-sense 15 polynucleotides, etc.

Antisense polynucleotides molecules are comprised of a complementary nucleotide sequence which allows them to hybridize specifically to designated regions of genomes or RNAs. Antisense polynucleotides may 20 include, for example, molecules that will block protein translation by binding to mRNA, or may be molecules which prevent replication of viral RNA by transcriptase. They may also include molecules which carry agents (non-covalently attached or covalently bound) which cause the 25 viral RNA to be inactive by causing, for example, scissions in the viral RNA. They may also bind to cellular polynucleotides which enhance and/or are required for viral infectivity, replicative ability, or chronicity. Antisense molecules which are to hybridize to HCV derived 30 RNAs may be designed based upon the sequence information of the HCV cDNAs provided herein. The antiviral agents based upon anti-sense polynucleotides for HCV may be designed to bind with high specificity, to be of increased solubility, to be stable, and to have low toxicity. Hence, 35 they may be delivered in specialized systems, for example, liposomes, or by gene therapy. In addition, they

may include analogs, attached proteins, substituted or altered bonding between bases, etc.

5 Other types of drugs may be based upon polynucleotides which "mimic" important control regions of the HCV genome, and which may be therapeutic due to their interactions with key components of the system responsible for viral infectivity or replication.

10 General Methods

The general techniques used in extracting the genome from a virus, preparing and probing a cDNA library, sequencing clones, constructing expression vectors, transforming cells, performing immunological assays such as 15 radioimmunoassays and ELISA assays, for growing cells in culture, and the like are known in the art and laboratory manuals are available describing these techniques. However, as a general guide, the following sets forth some 20 sources currently available for such procedures, and for materials useful in carrying them out.

Both prokaryotic and eukaryotic host cells may be used for expression of desired coding sequences when appropriate control sequences which are compatible with the designated host are used. Among prokaryotic hosts, E. 25 coli is most frequently used. Expression control sequences for prokaryotes include promoters, optionally containing operator portions, and ribosome binding sites. Transfer vectors compatible with prokaryotic hosts are 30 commonly derived from, for example, pBR322, a plasmid containing operons conferring ampicillin and tetracycline resistance, and the various pUC vectors, which also contain sequences conferring antibiotic resistance markers. These markers may be used to obtain successful 35 transformants by selection. Commonly used prokaryotic control sequences include the Beta-lactamase (penicillinase) and lactose promoter systems (Chang et al.

(1977)), the tryptophan (trp) promoter system (Goeddel et al. (1980)) and the lambda-derived P_L promoter and N gene ribosome binding site (Shimatake et al. (1981)) and the hybrid tac promoter (De Boer et al. (1983)) derived from sequences of the trp and lac UV5 promoters. The foregoing systems are particularly compatible with E. coli; if desired, other prokaryotic hosts such as strains of Bacillus or Pseudomonas may be used, with corresponding control sequences.

Eukaryotic hosts include yeast and mammalian cells in culture systems. Saccharomyces cerevisiae and Saccharomyces carlsbergensis are the most commonly used yeast hosts, and are convenient fungal hosts. Yeast compatible vectors carry markers which permit selection of successful transformants by conferring prototrophy to auxotrophic mutants or resistance to heavy metals on wild-type strains. Yeast compatible vectors may employ the 2 micron origin of replication (Broach et al. (1983)), the combination of CEN3 and ARS1 or other means for assuring replication, such as sequences which will result in incorporation of an appropriate fragment into the host cell genome. Control sequences for yeast vectors are known in the art and include promoters for the synthesis of glycolytic enzymes (Hess et al. (1968); Holland et al. (1978)), including the promoter for 3 phosphoglycerate kinase (Hitzeman (1980)). Terminators may also be included, such as those derived from the enolase gene (Holland (1981)). Particularly useful control systems are those which comprise the glyceraldehyde-3 phosphate dehydrogenase (GAPDH) promoter or alcohol dehydrogenase (ADH) regulatable promoter, terminators also derived from GAPDH, and if secretion is desired, leader sequence from yeast alpha factor. In addition, the transcriptional regulatory region and the transcriptional initiation region which are operably linked may be such that they are

not naturally associated in the wild-type organism. These systems are described in detail in EPO 120,551, published October 3, 1984; EPO 116,201, published August 22, 1984; 5 and EPO 164,556, published December 18, 1985, all of which are assigned to the herein assignee, and are hereby incorporated herein by reference.

Mammalian cell lines available as hosts for 10 expression are known in the art and include many immortalized cell lines available from the American Type Culture Collection (ATCC), including HeLa cells, Chinese hamster ovary (CHO) cells, baby hamster kidney (BHK) cells, and a number of other cell lines. Suitable promoters for mammalian cells are also known in the art and include viral 15 promoters such as that from Simian Virus 40 (SV40) (Fiers (1978)), Rous sarcoma virus (RSV), adenovirus (ADV), and bovine papilloma virus (BPV). Mammalian cells may also require terminator sequences and poly A addition sequences; enhancer sequences which increase expression 20 may also be included, and sequences which cause amplification of the gene may also be desirable. These sequences are known in the art. Vectors suitable for replication in mammalian cells may include viral replicons, or sequences 25 which insure integration of the appropriate sequences encoding NANBV epitopes into the host genome.

Transformation may be by any known method for 30 introducing polynucleotides into a host cell, including, for example packaging the polynucleotide in a virus and transducing a host cell with the virus, and by direct uptake of the polynucleotide. The transformation procedure used depends upon the host to be transformed. For example, transformation of the E. coli host cells with lambda-gt11 containing BB-NANBV sequences is discussed in 35 the Example section, infra. Bacterial transformation by direct uptake generally employs treatment with calcium or rubidium chloride (Cohen (1972); Maniatis (1982)). Yeast

5 transformation by direct uptake may be carried out using the method of Hinnen et al. (1978). Mammalian transformations by direct uptake may be conducted using the calcium phosphate precipitation method of Graham and Van der Eb (1978), or the various known modifications thereof.

10 Vector construction employs techniques which are known in the art. Site-specific DNA cleavage is performed by treating with suitable restriction enzymes under conditions which generally are specified by the manufacturer of these commercially available enzymes. In general, about 1 microgram of plasmid or DNA sequence is cleaved by 1 unit of enzyme in about 20 microliters buffer solution by 15 incubation of 1-2 hr at 37° C. After incubation with the restriction enzyme, protein is removed by phenol/ chloroform extraction and the DNA recovered by precipitation with ethanol. The cleaved fragments may be separated using polyacrylamide or agarose gel electrophoresis 20 techniques, according to the general procedures found in Methods in Enzymology (1980) 65:499-560.

25 Sticky ended cleavage fragments may be blunt ended using E. coli DNA polymerase I (Klenow) in the presence of the appropriate deoxynucleotide triphosphates (dNTPs) present in the mixture. Treatment with S1 nuclease may also be used, resulting in the hydrolysis of any single stranded DNA portions.

30 Ligations are carried out using standard buffer and temperature conditions using T4 DNA ligase and ATP; sticky end ligations require less ATP and less ligase than blunt end ligations. When vector fragments are used as part of a ligation mixture, the vector fragment is often treated with bacterial alkaline phosphatase (BAP) or calf intestinal alkaline phosphatase to remove the 5'-phosphate 35 and thus prevent religation of the vector; alternatively, restriction enzyme digestion of unwanted fragments can be used to prevent ligation.

5 Ligation mixtures are transformed into suitable cloning hosts, such as E. coli, and successful transformants selected by, for example, antibiotic resistance, and screened for the correct construction.

10 Synthetic oligonucleotides may be prepared using an automated oligonucleotide synthesizer as described by Warner (1984). If desired the synthetic strands may be labeled with ^{32}P by treatment with polynucleotide kinase in the presence of ^{32}P -ATP, using standard conditions for the reaction.

15 DNA sequences, including those isolated from cDNA libraries, may be modified by known techniques, including, for example site directed mutagenesis, as described by Zoller (1982). Briefly, the DNA to be modified is packaged into phage as a single stranded sequence, and converted to a double stranded DNA with DNA polymerase using, as a primer, a synthetic oligonucleotide complementary to the portion of the DNA to be modified, 20 and having the desired modification included in its own sequence. The resulting double stranded DNA is transformed into a phage supporting host bacterium. Cultures of the transformed bacteria, which contain 25 replications of each strand of the phage, are plated in agar to obtain plaques. Theoretically, 50% of the new plaques contain phage having the mutated sequence, and the remaining 50% have the original sequence. Replicates of the plaques are hybridized to labeled synthetic probe at 30 temperatures and conditions which permit hybridization with the correct strand, but not with the unmodified sequence. The sequences which have been identified by hybridization are recovered and cloned.

35 DNA libraries may be probed using the procedure of Grunstein and Hogness (1975). Briefly, in this procedure, the DNA to be probed is immobilized on nitrocellulose filters, denatured, and prehybridized with a

buffer containing 0-50% formamide, 0.75 M NaCl, 75 mM Na citrate, 0.02% (wt/v) each of bovine serum albumin, polyvinyl pyrrolidone, and Ficoll, 50 mM Na Phosphate (pH 5.5), 0.1% SDS, and 100 micrograms/ml carrier denatured DNA. The percentage of formamide in the buffer, as well as the time and temperature conditions of the prehybridization and subsequent hybridization steps depends on the stringency required. Oligomeric probes 10 which require lower stringency conditions are generally used with low percentages of formamide, lower temperatures, and longer hybridization times. Probes containing more than 30 or 40 nucleotides such as those derived from cDNA or genomic sequences generally employ 15 higher temperatures, e.g., about 40-42°C, and a high percentage, e.g., 50%, formamide. Following prehybridization, 5'-³²P-labeled oligonucleotide probe is added to the buffer, and the filters are incubated in this mixture under hybridization conditions. After washing, 20 the treated filters are subjected to autoradiography to show the location of the hybridized probe; DNA in corresponding locations on the original agar plates is used as the source of the desired DNA.

For routine vector constructions, ligation 25 mixtures are transformed into E. coli strain HB101 or other suitable host, and successful transformants selected by antibiotic resistance or other markers. Plasmids from the transformants are then prepared according to the method of Clewell et al. (1969), usually following 30 chloramphenicol amplification (Clewell (1972)). The DNA is isolated and analyzed, usually by restriction enzyme analysis and/or sequencing. Sequencing may be by the dideoxy method of Sanger et al. (1977) as further described by Messing et al. (1981), or by the method of 35 Maxam et al. (1980). Problems with band compression, which are sometimes observed in GC rich regions, were

overcome by use of T-deazoguanosine according to Barr et al. (1986).

5 The enzyme-linked immunosorbent assay (ELISA) can be used to measure either antigen or antibody concentrations. This method depends upon conjugation of an enzyme to either an antigen or an antibody, and uses the bound enzyme activity as a quantitative label. To 10 measure antibody, the known antigen is fixed to a solid phase (e.g., a microplate or plastic cup), incubated with test serum dilutions, washed, incubated with anti-immunoglobulin labeled with an enzyme, and washed again. Enzymes suitable for labeling are known in the art, and 15 include, for example, horseradish peroxidase. Enzyme activity bound to the solid phase is measured by adding the specific substrate, and determining product formation or substrate utilization colorimetrically. The enzyme activity bound is a direct function of the amount of antibody bound.

20 To measure antigen, a known specific antibody is fixed to the solid phase, the test material containing antigen is added, after an incubation the solid phase is washed, and a second enzyme-labeled antibody is added. After washing, substrate is added, and enzyme activity is 25 estimated colorimetrically, and related to antigen concentration.

Examples

30 Described below are examples of the present invention which are provided only for illustrative purposes, and not to limit the scope of the present invention. In light of the present disclosure, numerous embodiments within the scope of the claims will be apparent to those of ordinary skill in the art.

Isolation and Sequence of OverlappingHCV cDNA Clones 13i, 26j, CA59a, CA84a, CA156e and CA167b

5 The clones 13i, 26j, CA59a, CA84a, CA156e and CA167b were isolated from the lambda-gt11 library which contains HCV cDNA (ATCC No. 40394), the preparation of which is described in EPO Pub. No. 318,216 (published 31 May 1989), and WO 89/04669 (published 1 June 1989).

10 Screening of the library was with the probes described infra., using the method described in Huynh (1985). The frequencies with which positive clones appeared with the respective probes was about 1 in 50,000.

15 The isolation of clone 13i was accomplished using a synthetic probe derived from the sequence of clone 12f. The sequence of the probe was:

5' GAA CGT TGC GAT CTG GAA GAC AGG GAC AGG 3'.

20 The isolation of clone 26j was accomplished using a probe derived from the 5'-region of clone K9-1. The sequence of the probe was:

5' TAT CAG TTA TGC CAA CGG AAG CGG CCC CGA 3'.

25 The isolation procedures for clone 12f and for clone k9-1 (also called K9-1) are described in EPO Pub. No. 318,216, and their sequences are shown in Figs. 1 and 2, respectively. The HCV cDNA sequences of clones 13i and 26j, are shown in Figs. 4 and 5, respectively. Also shown 30 are the amino acids encoded therein, as well as the overlap of clone 13i with clone 12f, and the overlap of clone 26j with clone 13i. The sequences for these clones confirmed the sequence of clone K9-1. Clone K9-1 had been 35 isolated from a different HCV cDNA library (See EP 0,218,316).

Clone CA59a was isolated utilizing a probe based upon the sequence of the 5'-region of clone 26j. The sequence of this probe was:

5

5' CTG GTT AGC AGG GCT TTT CTA TCA CCA CAA 3'.

A probe derived from the sequence of clone CA59a was used to isolate clone CA84a. The sequence of the 10 probe used for this isolation was:

10

5' AAG GTC CTG GTA GTG CTG CTG CTA TTT GCC 3'.

15

Clone CA156e was isolated using a probe derived from the sequence of clone CA84a. The sequence of the probe was:

5' ACT GGA CGA CGC AAG GTT GCA ATT GCT CTA 3'.

20

Clone CA167b was isolated using a probe derived from the sequence of clone CA 156e. The sequence of the probe was:

25

5' TTC GAC GTC ACA TCG ATC TGC TTG TCG GGA 3'.

30

The nucleotide sequences of the HCV cDNAs in clones CA59a, CA84a, CA156e, and CA167b, are shown Figs. 6, 7, 8, and 9, respectively. The amino acids encoded therein, as well as the overlap with the sequences of relevant clones, are also shown in the Figs.

Creation of "pi" HCV cDNA Library

A library of HCV cDNA, the "pi" library, was constructed from the same batch of infectious chimpanzee plasma used to construct the lambda-gt11 HCV cDNA library (ATCC No. 40394) described in EPO Pub. No. 318,216, and

35

utilizing essentially the same techniques. However, construction of the pi library utilized a primer-extension method, in which the primer for reverse transcriptase was based on the sequence of clone CA59A. The sequence of the primer was:

5' GGT GAC GTG GGT TTC 3'.

10

Isolation and Sequence of Clone pil4a

Screening of the "pi" HCV cDNA library described supra., with the probe used to isolate clone CA167b (See supra.) yielded clone pil4a. The clone contains about 800 base pairs of cDNA which overlaps clones CA167b, CA156e, CA84a and CA59a, which were isolated from the lambda gt-11 HCV cDNA library (ATCC No. 40394). In addition, pil4a also contains about 250 base pairs of DNA which are upstream of the HCV cDNA in clone CA167b.

20

Isolation and Sequence of Clones CA216a, CA290a and ag30a

Based on the sequence of clone CA167b a synthetic probe was made having the following sequence:

25

5' GGC TTT ACC ACG TCA CCA ATG ATT GCC CTA 3'

30

The above probe was used to screen the , which yielded clone CA216a, whose HCV sequences are shown in Fig. 10.

Another probe was made based on the sequence of clone CA216a having the following sequence:

5' TTT GGG TAA GGT CAT CGA TAC CCT TAC GTG 3'

35

Screening the lambda-gt11 library (ATCC No. 40394) with this probe yielded clone CA290a, the HCV sequences therein being shown in Fig. 11.

5 In a parallel approach, a primer-extension cDNA library was made using nucleic acid extracted from the same infectious plasma used in the original lambda-gt11 cDNA library described above. The primer used was based on the sequence of clones CA216a and CA290a:

5' GAA GCC GCA CGT AAG 3'

10 10 The cDNA library was made using methods similar to those described previously for libraries used in the isolation of clones p114a and k9-1. The probe used to screen this library was based on the sequence of clone CA290a:

15 15 5' CCG GCG TAG GTC GCG CAA TTT GGG TAA 3'

20 20 Clone ag30a was isolated from the new library with the above probe, and contained about 670 basepairs of HCV sequence. See Fig. 12. Part of this sequence overlaps the HCV sequence of clones CA216a and CA290a. About 300 base-pairs of the ag30a sequence, however, is upstream of the sequence from clone CA290a. The non-overlapping sequence shows a start codon (*) and stop codons that may indicate the start of the HCV ORF. Also indicated in Fig. 25 25 12 are putative small encoded peptides (#) which may play a role in regulating translation, as well as the putative first amino acid of the putative polypeptide (/), and downstream amino acids encoded therein.

30 30 Isolation and Sequence of Clone CA205a

35 35 Clone CA205a was isolated from the original lambda gt-11 library (ATCC No. 40394), using a synthetic probe derived from the HCV sequence in clone CA290a (Fig. 11). The sequence of the probe was:

5' TCA GAT CGT TGG TGG AGT TTA CTT GTT GCC 3'.

5 The sequence of the HCV cDNA in CA205a, shown in Fig. 13, overlaps with the cDNA sequences in both clones ag30a and CA290a. The overlap of the sequence with that of CA290a is shown by the dotted line above the sequence (the figure also shows the putative amino acids encoded in this fragment).

10 As observed from the HCV cDNA sequences in clones CA205a and ag30a, the putative HCV polyprotein appears to begin at the ATG start codon; the HCV sequences in both clones contain an in-frame, contiguous double stop codon (TGATAG) forty two nucleotides upstream from this ATG. The HCV ORF appears to begin after these stop codons, and to extend for at least 8907 nucleotides (See 15 the composite HCV cDNA shown in Fig. 17).

Isolation and Sequence of Clone 18g

20 Based on the sequence of clone ag30a (See Fig. 12) and of an overlapping clone from the original lambda gt-11 library (ATCC No. 40394), CA230a, a synthetic probe was made having the following sequence:

5' CCA TAG TGG TCT GCG GAA CCG GTG AGT ACA 3'.

25 Screening of the original lambda-gt11 HCV cDNA library with the probe yielded clone 18g, the HCV cDNA sequence of which is shown in Fig. 14. Also shown in the figure are the overlap with clone ag30a, and putative polypeptides encoded within the HCV cDNA.

30 The cDNA in clone 18g (C18g or 18g) overlaps that in clones ag30a and CA205a, described supra. The sequence of C18g also contains the double stop codon region observed in clone ag30a. The polynucleotide region upstream of these stop codons presumably represents part 35 of the 5'-region of the HCV genome, which may contain short ORFs, and which can be confirmed by direct sequenc-

ing of the purified HCV genome. These putative small encoded peptides may play a regulatory role in translation. The region of the HCV genome upstream of that 5 represented by C18g can be isolated for sequence analysis using essentially the technique described in EPO Pub. No. 318,216 for isolating cDNA sequences upstream of the HCV cDNA sequence in clone 12f. Essentially, small synthetic oligonucleotide primers of reverse transcriptase, which 10 are based upon the sequence of C18g, are synthesized and used to bind to the corresponding sequence in HCV genomic RNA. The primer sequences are proximal to the known 5'-terminal of C18g, but sufficiently downstream to allow the design of probe sequences upstream of the primer 15 sequences. Known standard methods of priming and cloning are used. The resulting cDNA libraries are screened with sequences upstream of the priming sites (as deduced from the elucidated sequence of C18g). The HCV genomic RNA is obtained from either plasma or liver samples from 20 individuals with NANBH. Since HCV appears to be a Flavi-like virus, the 5'-terminus of the genome may be modified with a "cap" structure. It is known that Flavivirus genomes contain 5'-terminal "cap" structures. (Yellow Fever virus, Rice et al. (1988); Dengue virus, Hahn et al 25 (1988); Japanese Encephalitis Virus (1987)).

Isolation and Sequence of Clones from
the beta-HCV cDNA library

30 Clones containing cDNA representative of the 3'-terminal region of the HCV genome were isolated from a cDNA library constructed from the original infectious chimpanzee plasma pool which was used for the creation of the HCV cDNA lambda-gt11 library (ATCC No. 40394), described in EPO Pub. No. 318,216. In order to create the 35 DNA library, RNA extracted from the plasma was "tailed" with poly rA using poly (rA) polymerase, and cDNA was

synthesized using oligo(dT)₁₂₋₁₈ as a primer for reverse transcriptase. The resulting RNA:cDNA hybrid was digested with RNAase H, and converted to double stranded HCV cDNA.

5 The resulting HCV cDNA was cloned into lambda-gt10, using essentially the technique described in Huynh (1985), yielding the beta (or b) HCV cDNA library. The procedures used were as follows.

10 An aliquot (12ml) of the plasma was treated with proteinase K, and extracted with an equal volume of phenol saturated with 0.05M Tris-Cl, pH 7.5, 0.05% (v/v) beta-mercaptoethanol, 0.1% (w/v) hydroxyquinolone, 1 mM EDTA. The resulting aqueous phase was re-extracted with the phenol mixture, followed by 3 extractions with a 1:1

15 mixture containing phenol and chloroform:isoamyl alcohol (24:1), followed by 2 extractions with a mixture of chloroform and isoamyl alcohol (1:1). Subsequent to adjustment of the aqueous phase to 200 mM with respect to NaCl, nucleic acids in the aqueous phase were precipitated overnight at -20°C, with 2.5 volumes of cold absolute ethanol. The precipitates were collected by centrifugation at 10,000 RPM for 40 min., washed with 70% ethanol containing 20 mM NaCl, and with 100% cold ethanol, dried for 5 min. in a dessicator, and dissolved in water.

20

25 The isolated nucleic acids from the infectious chimpanzee plasma pool were tailed with poly rA utilizing poly-A polymerase in the presence of human placenta ribonuclease inhibitor (HPRI) (purchased from Amersham Corp.), utilizing MS2 RNA as carrier. Isolated nucleic acids equivalent to that in 2 ml of plasma were incubated in a solution containing TMN (50 mM Tris HCl, pH 7.9, 10 mM MgCl₂, 250 mM NaCl, 2.5 mM MnCl₂, 2 mM dithiothreitol (DTT)), 40 micromolar alpha-[³²P] ATP, 20 units HPRI (Amersham Corp.), and about 9 to 10 units of RNase free poly-A polymerase (BRL). Incubation was for 10 min. at 37°C, and the reactions were stopped with EDTA (final

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concentration about 250 mM). The solution was extracted with an equal volume of phenol-chloroform, and with an equal volume of chloroform, and nucleic acids were 5 precipitated overnight at -20°C with 2.5 volumes of ethanol in the presence of 200 mM NaCl.

Isolation of Clone b5a

10 The beta HCV cDNA library was screened by hybridization using a synthetic probe, which had a sequence based upon the HCV cDNA sequence in clone 15e. The isolation of clone 15e is described in EPO Pub. No. 318,216, and its sequence is shown in Fig. 3. The 15 sequence of the synthetic probe was:

5' ATT GCG AGA TCT ACG GGG CCT GCT ACT CCA 3'.

20 Screening of the library yielded clone beta-5a (b5a), which contains an HCV cDNA region of approximately 1000 base pairs. The 5'-region of this cDNA overlaps clones 35f, 19g, 26g, and 15e (these clones are described supra). The region between the 3'-terminal poly-A sequence and the 25 3'-sequence which overlaps clone 15e, contains approximately 200 base pairs. This clone allows the identification of a region of the 3'-terminal sequence the HCV genome.

30 The sequence of b5a is contained within the sequence of the HCV cDNA in clone 16jh (described infra). Moreover, the sequence is also present in CC34a, isolated from the original lambda-gt11 library (ATCC No. 40394). (The original lambda-gt11 library is referred to herein as the "C" library).

Isolation and Sequence of Clones Generated by PCR
Amplification of the 3'-Region of the HCV Genome

5 Multiple cDNA clones have been generated which
contain nucleotide sequences derived from the 3'-region of
the HCV genome. This was accomplished by amplifying a
targeted region of the genome by a polymerase chain re-
action technique described in Saiki et al. (1986), and in
10 Saiki et al. (1988), which was modified as described
below. The HCV RNA which was amplified was obtained from
the original infectious chimpanzee plasma pool which was
used for the creation of the HCV cDNA lambda-gt11 library
(ATCC No. 40394) described in EPO Pub. No. 318,216.
15 Isolation of the HCV RNA was as described supra. The
isolated RNA was tailed at the 3'-end with ATP by E. coli
poly-A polymerase as described in Sippel (1973), except
that the nucleic acids isolated from chimp serum were
substituted for the nucleic acid substrate. The tailed
20 RNA was then reverse transcribed into cDNA by reverse
transcriptase, using an oligo dT-primer adapter, es-
sentially as described by Han (1987), except that the
components and sequence of the primer-adapter were:

25 Stuffer NotI SP6 Promoter Primer
AATTC GCGGCCGC CATACTGATTTAGGTGACACTATAGAA T₁₅

The resultant cDNA was subjected to amplification by PCR
using two primers:

30 Primer Sequence
JH32 (30mer) ATAGCGGCCGCCCTCGATTGCGAGATCTAC
JH11 (20mer) AATTCTGGCGGCCGCCATACGA

35 The JH32 primer contained 20 nucleotide sequences
hybridizable to the 5'-end of the target region in the
cDNA, with an estimated T_m of 66°C. The JH11 was derived

from a portion of the oligo dT-primer adapter; thus, it is specific to the 3'-end of the cDNA with a T_m of 64°C.

5 Both primers were designed to have a recognition site for the restriction enzyme, NotI, at the 5'-end, for use in subsequent cloning of the amplified HCV cDNA.

10 The PCR reaction was carried out by suspending the cDNA and the primers in 100 microliters of reaction mixture containing the four deoxynucleoside triphosphates, buffer salts and metal ions, and a thermostable DNA polymerase isolated from Thermus aquaticus (Taq polymerase), which are in a Perkin Elmer Cetus PCR kit (N801-0043 or N801-0055). The PCR reaction was performed for 35 cycles in a Perkin Elmer Cetus DNA thermal cycler.

15 Each cycle consisted of a 1.5 min denaturation step at 94°C, an annealing step at 60°C for 2 min, and a primer extension step at 72°C for 3 min. The PCR products were subjected to Southern blot analysis using a 30 nucleotide probe, JH34, the sequence of which was based upon that of the 3'-terminal region of clone 15e. The sequence of JH34 is:

5' CTT GAT CTA CCT CCA ATC ATT CAA AGA CTC 3'.

25 The PCR products detected by the HCV cDNA probe ranged in size from about 50 to about 400 base pairs.

30 In order to clone the amplified HCV cDNA, the PCR products were cleaved with NotI and size selected by polyacrylamide gel electrophoresis. DNA larger than 300 base pairs was cloned into the NotI site of pUC18S. The vector pUC18S is constructed by including a NotI polylinker cloned between the EcoRI and SalI sites of pUC18. The clones were screened for HCV cDNA using the JH34 probe. A number of positive clones were obtained and sequenced. The nucleotide sequence of the HCV cDNA insert in one of these clones, 16jh, and the amino acids encoded

therein, are shown in Fig. 15. A nucleotide heterogeneity, detected in the sequence of the HCV cDNA in clone 16jh as compared to another clone of this region, is 5 indicated in the figure.

Compiled HCV cDNA Sequences

An HCV cDNA sequence has been compiled from a series of overlapping clones derived from the various HCV 10 cDNA libraries described supra.. In this sequence, the compiled HCV cDNA sequence obtained from clones b114a, 18g, ag30a, CA205a, CA290a, CA216a, pil4a, CA167b, CA156e, CA84a, and CA59a is upstream of the compiled HCV cDNA 15 sequence published in EPO Pub. No. 318,216, which is shown in Fig. 16. The compiled HCV cDNA sequence obtained from clones b5a and 16jh downstream of the compiled HCV cDNA sequence published in EPO Pub. No. 318,216.

Fig. 17 shows the compiled HCV cDNA sequence 20 derived from the above-described clones and the compiled HCV cDNA sequence published in EPO Pub. No. 318,216. The clones from which the sequence was derived are b114a, 18g, ag30a, CA205a, CA290a, CA216a, pil4a, CA167b, CA156e, CA84a, CA59a, K9-1 (also called k9-1), 26j, 13i, 12f, 14i, 25 11b, 7f, 7e, 8h, 33c, 40b, 37b, 35, 36, 81, 32, 33b, 25c, 14c, 8f, 33f, 33g, 39c, 35f, 19g, 26g, 15e, b5a, and 16jh. In the figure the three dashes above the sequence indicate the position of the putative initiator methionine codon.

Clone b114a was obtained using the cloning 30 procedure described for clone b5a, supra., except that the probe was the synthetic probe used to detect clone 18g, supra. Clone b114a overlaps with clones 18g, ag30a, and CA205a, except that clone b114a contains an extra two nucleotides upstream of the sequence in clone 18g (i.e., 5'-CA). These extra two nucleotides have been included in 35 the HCV genomic sequence shown in Fig. 17.

It should be noted that although several of the clones described supra. have been obtained from libraries other than the original HCV cDNA lambda-gt11 C library (ATCC No. 40394), these clones contain HCV cDNA sequences which overlap HCV cDNA sequences in the original library. Thus, essentially all of the HCV sequence is derivable from the original lambda-gt11 C library (ATCC No. 40394) which was used to isolate the first HCV cDNA clone (5-1-1). The isolation of clone 5-1-1 is described in EPO Pub. No. 318,216.

Purification of Fusion Polypeptide C100-3
(Alternate method)

The fusion polypeptide, C100-3 (also called HCV c100-3 and alternatively, c100-3), is comprised of superoxide dismutase (SOD) at the N-terminus and an in-frame C100 HCV polypeptide at the C-terminus. A method for preparing the polypeptide by expression in yeast, and differential extraction of the insoluble fraction of the extracted host yeast cells, is described in EPO Pub. No. 318,216. An alternative method for the preparation of this fusion polypeptide is described below. In this method the antigen is precipitated from the crude cell lysate with acetone; the acetone precipitated antigen is then subjected to ion-exchange chromatography, and further purified by gel filtration.

The fusion polypeptide, C100-3 (HCV c100-3), is expressed in yeast strain JSC 308 (ATCC No. 20879) transformed with pAB24C100-3 (ATCC No. 67976); the transformed yeast are grown under conditions which allow expression (i.e., by growth in YEP containing 1% glucose). (See EPO Pub. No. 318,216). A cell lysate is prepared by suspending the cells in Buffer A (20 mM Tris HCl, pH 8.0, 1 mM EDTA, 1 mM PMSF. The cells are broken by grinding with glass beads in a Dynomill type homogenizer or its

equivalent. The extent of cell breakage is monitored by counting cells under a microscope with phase optics.

5 Broken cells appear dark, while viable cells are light-colored. The percentage of broken cells is determined.

When the percentage of broken cells is approximately 90% or greater, the broken cell debris is separated from the glass beads by centrifugation, and the glass beads are washed with Buffer A. After combining the washes and homogenate, the insoluble material in the lysate is obtained by centrifugation. The material in the pellet is washed to remove soluble proteins by suspension in Buffer B (50 mM glycine, pH 12.0, 1 mM DTT, 500 mM NaCl), followed by Buffer C (50 mM glycine, pH 10.0, 1 mM DTT). The insoluble material is recovered by centrifugation, and solubilized by suspension in Buffer C containing SDS. The extract solution may be heated in the presence of beta-mercaptoethanol and concentrated by ultrafiltration. The HCV c100-3 in the extract is precipitated with cold acetone. If desired, the precipitate may be stored at temperatures at about or below -15°C.

Prior to ion exchange chromatography, the acetone precipitated material is recovered by centrifugation, and may be dried under nitrogen. The precipitate is suspended in Buffer D (50 mM glycine, pH 10.0, 1 mM DTT, 7 M urea), and centrifuged to pellet insoluble material. The supernatant material is applied to an anion exchange column previously equilibrated with Buffer D. Fractions are collected and analyzed by ultraviolet absorbance or gel electrophoresis on SDS polyacrylamide gels. Those fractions containing the HCV c100-3 polypeptide are pooled.

35 In order to purify the HCV c100-3 polypeptide by gel filtration, the pooled fractions from the ion-exchange column are heated in the presence of beta-mercaptoethanol

and SDS, and the eluate is concentrated by ultrafiltration. The concentrate is applied to a gel filtration column previously equilibrated with Buffer E (20 mM Tris HCl, pH 7.0, 1 mM DTT, 0.1% SDS). The presence of HCV c100-3 in the eluted fractions, as well as the presence of impurities, are determined by gel electrophoresis on polyacrylamide gels in the presence of SDS and visualization of the polypeptides. Those fractions containing purified HCV c100-3 are pooled. Fractions high in HCV c100-3 may be further purified by repeating the gel filtration process. If the removal of particulate material is desired, the HCV c100-3 containing material may be filtered through a 0.22 micron filter.

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Expression and Antigenicity of Polypeptides
Encoded in HCV cDNA

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Polypeptides Expressed in E. coli

The polypeptides encoded in a number of HCV cDNAs which span the HCV genomic ORF were expressed in E. coli, and tested for their antigenicity using serum obtained from a variety of individuals with NANBH.

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The expression vectors containing the cloned HCV cDNAs were constructed from pSODcfl (Steimer et al. (1986)). In order to be certain that a correct reading frame would be achieved, three separate expression vectors, pcflAB, pcflCD, and pcflEF were created by ligating either of three linkers, AB, CD, and EF to a BamHI-EcoRI fragment derived by digesting to completion the vector pSODcfl with EcoRI and BamHI, followed by treatment with alkaline phosphatase. The linkers were created from six oligomers, A, B, C, D, E, and F. Each oligomer was phosphorylated by treatment with kinase in the presence of ATP prior to annealing to its complementary oligomer. The sequences of the synthetic linkers were the following.

35

	<u>Name</u>	<u>DNA Sequence (5' to 3')</u>
5	A	GATC CTG AAT TCC TGA TAA
	B	GAC TTA AGG ACT ATT TTA A
	C	GATC CGA ATT CTG TGA TAA
10	D	GCT TAA GAC ACT ATT TTA A
	E	GATC CTG GAA TTC TGA TAA
	F	GAC CTT AAG ACT ATT TTA A

15 Each of the three linkers destroys the original EcoRI site, and creates a new EcoRI site within the linker, but within a different reading frame. Hence, the HCV cDNA EcoRI fragments isolated from the clones when inserted into the expression vector, were in three different reading frames.

20 The HCV cDNA fragments in the designated lambda-gt11 clones were excised by digestion with EcoRI; each fragment was inserted into pcflAB, pcflCD, and pcflEF. These expression constructs were then transformed into D1210 E. coli cells, the transformants were cloned, and 25 recombinant bacteria from each clone were induced to express the fusion polypeptides by growing the bacteria in the presence of IPTG.

30 Expression products of the indicated HCV cDNAs were tested for antigenicity by direct immunological screening of the colonies, using a modification of the method described in Helfman et al. (1983). Briefly, as shown in Fig. 18, the bacteria were plated onto nitrocellulose filters overlaid on ampicillin plates to give approximately 1,000 colonies per filter. Colonies were 35 replica plated onto nitrocellulose filters, and the replicas were regrown overnight in the presence of 2 mM

IPTG and ampicillin. The bacterial colonies were lysed by suspending the nitrocellulose filters for about 15 to 20 min in an atmosphere saturated with CHCl_3 vapor. Each 5 filter then was placed in an individual 100 mm Petri dish containing 10 ml of 50 mM Tris HCl, pH 7.5, 150 mM NaCl, 5 mM MgCl_2 , 3% (w/v) BSA, 40 micrograms/ml lysozyme, and 0.1 microgram/ml DNase. The plates were agitated gently for at least 8 hours at room temperature. The filters were 10 rinsed in TBST (50 mM Tris HCl, pH 8.0, 150 mM NaCl, 0.005% Tween 20). After incubation, the cell residues were rinsed and incubated in TBS (TBST without Tween) containing 10% sheep serum; incubation was for 1 hour. The filters were then incubated with pretreated sera in TBS 15 from individuals with NANBH, which included: 3 chimpanzees; 8 patients with chronic NANBH whose sera were positive with respect to antibodies to HCV C100-3 polypeptide (described in EPO Pub. No. 318,216, and supra.) (also called C100); 8 patients with chronic NANBH 20 whose sera were negative for anti-C100 antibodies; a convalescent patient whose serum was negative for anti-C100 antibodies; and 6 patients with community acquired NANBH, including one whose sera was strongly positive with respect to anti-C100 antibodies, and one whose sera was 25 marginally positive with respect to anti-C100 antibodies. The sera, diluted in TBS, was pretreated by preabsorption with hSOD. Incubation of the filters with the sera was for at least two hours. After incubation, the filters were washed two times for 30 min with TBST. Labeling of 30 expressed proteins to which antibodies in the sera bound was accomplished by incubation for 2 hours with ^{125}I -labeled sheep anti-human antibody. After washing, the filters were washed twice for 30 min with TBST, dried, and autoradiographed. 35 A number of clones (see infra.) expressed polypeptides containing HCV epitopes which were im-

munologically reactive with serum from individuals with NANBH. Five of these polypeptides were very immunogenic in that antibodies to HCV epitopes in these polypeptides 5 were detected in many different patient sera. The clones encoding these polypeptides, and the location of the polypeptide in the putative HCV polyprotein (wherein the amino acid numbers begin with the putative initiator 10 codon) are the following: clone 5-1-1, amino acids 1694- 1735; clone C100, amino acids 1569-1931; clone 33c, amino acids 1192-1457; clone CA279a, amino acids 1-84; and clone CA290a amino acids 9-177. The location of the immunogenic polypeptides within the putative HCV polyprotein are shown 15 immediately below.

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5 Clones encoding polypeptides of proven reactivity
 with sera from NANBH patients.

	<u>Clone</u>	<u>Location within the HCV polyprotein</u> (amino acid no. beginning with puta- tive initiator methionine)
10	CA279a	1-84
	CA74a	437-582
	13i	511-690
	CA290a	9-177
15	33c	1192-1457
	40b	1266-1428
	5-1-1	1694-1735
	81	1689-1805
	33b	1916-2021
20	25c	1949-2124
	14c	2054-2223
	8f	2200-3325
	33f	2287-2385
	33g	2348-2464
25	39c	2371-2502
	15e	2796-2886
	C100	1569-1931

30 The results on the immunogenicity of the
 polypeptides encoded in the various clones examined sug-
 gest efficient detection and immunization systems may
 include panels of HCV polypeptides/epitopes.

35 Expression of HCV Epitopes in Yeast
 Three different yeast expression vectors which
 allow the insertion of HCV cDNA into three different read-

ing frames are constructed. The construction of one of the vectors, pAB24C100-3 is described in EPO Pub. No. 318,216. In the studies below, the HCV cDNA from the 5 clones listed in supra. in the antigenicity mapping study using the E. coli expressed products are substituted for the C100 HCV cDNA. The construction of the other vectors replaces the adaptor described in the above E. coli studies with one of the following adaptors:

10

Adaptor 1

ATT TTG AAT TCC TAA TGA G
AC TTA AGG ATT ACT CAG CT

15

Adaptor 2

AAT TTG GAA TTC TAA TGA G
AC CTT AAG ATT ACT CAG CT.

20

The inserted HCV cDNA is expressed in yeast transformed with the vectors, using the expression conditions described supra. for the expression of the fusion polypeptide, C100-3. The resulting polypeptides are 25 screened using the sera from individuals with NANBH, described supra. for the screening of immunogenic polypeptides encoded in HCV cDNAs expressed in E. coli.

30

Comparison of the Hydrophobic Profiles of HCV Polyproteins with West Nile Virus Polyprotein and with Dengue Virus NS1

The hydrophobicity profile of an HCV polyprotein segment was compared with that of a typical Flavivirus, West Nile virus. The polypeptide sequence of the West 35 Nile virus polyprotein was deduced from the known polynucleotide sequences encoding the non-structural

proteins of that virus. The HCV polyprotein sequence was deduced from the sequence of overlapping cDNA clones. The profiles were determined using an antigen program which 5 uses a window of 7 amino acid width (the amino acid in question, and 3 residues on each side) to report the average hydrophobicity about a given amino acid residue. The parameters giving the reactive hydrophobicity for each amino acid residue are from Kyte and Doolittle (1982).
10 Fig. 19 shows the hydrophobic profiles of the two polyproteins; the areas corresponding to the non-structural proteins of West Nile virus, ns1 through ns5, are indicated in the figure. As seen in the figure, there is a general similarity in the profiles of the HCV 15 polyprotein and the West Nile virus polyprotein.

The sequence of the amino acids encoded in the 5'-region of HCV cDNA shown in Fig. 16 has been compared with the corresponding region of one of the strains of 20 Dengue virus, described supra., with respect to the profile of regions of hydrophobicity and hydrophilicity (data not shown). This comparison indicated that the polypeptides from HCV and Dengue encoded in this region, which corresponds to the region encoding NS1 (or a portion thereof), have a similar hydrophobic/hydrophilic profile.
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The similarity in hydrophobicity profiles, in combination with the previously identified homologies in the amino acid sequences of HCV and Dengue Flavivirus in EP 0,218,316 suggests that HCV is related to these members 30 of the Flavivirus family.

Characterization of the Putative Polypeptides Encoded Within the HCV ORF

The sequence of the HCV cDNA sense strand, shown 35 in Fig. 17, was deduced from the overlapping HCV cDNAs in the various clones described in EPO Pub. No. 318,216 and those described supra. It may be deduced from the

sequence that the HCV genome contains primarily one long continuous ORF, which encodes a polyprotein. In the sequence, nucleotide number 1 corresponds to the first 5 nucleotide of the initiator MET codon; minus numbers indicate that the nucleotides are that distance away in the 5'-direction (upstream), while positive numbers indicate that the nucleotides are that distance away in the 10 3'-direction (downstream). The composite sequence shows the "sense" strand of the HCV cDNA.

The amino acid sequence of the putative HCV polyprotein deduced from the HCV cDNA sense strand sequence is also shown in Fig. 17, where position 1 begins with the putative initiator methionine.

15 Possible protein domains of the encoded HCV polyprotein, as well as the approximate boundaries, are the following (the polypeptides identified within the parentheses are those which are encoded in the Flavivirus domain):

20

	<u>Putative Domain</u>	<u>Approximate Boundary (amino acid nos.)</u>
25	"C" (nucleocapsid protein)	1-120
	"E" (Virion envelope protein(s) and possibly matrix (M) proteins	120-400
30	"NS1" (complement fixation antigen?)	400-660
	"NS2" (unknown function)	660-1050
35	"NS3" (protease?)	1050-1640

"NS4" (unknown function)

1640-2000

"NS5" (polymerase)

2000-? end

5

It should be noted, however, that hydrophobicity profiles (described infra), indicate that HCV diverges from the Flavivirus model, particularly with respect to the region upstream of NS2. Moreover, the boundaries indicated are
10 not intended to show firm demarcations between the putative polypeptides.

15

The Hydrophilic and Antigenic Profile of the Polypeptide
Profiles of the hydrophilicity/hydrophobicity

20 and the antigenic index of the putative polyprotein encoded in the HCV cDNA sequence shown in Fig. 16 were determined by computer analysis. The program for hydrophilicity/hydrophobicity was as described supra. The antigenic index results from a computer program which
25 relies on the following criteria: 1) surface probability, 2) prediction of alpha-helicity by two different methods; 3) prediction of beta-sheet regions by two different methods; 4) prediction of U-turns by two different methods; 5) hydrophilicity/hydrophobicity; and flexibility. The traces of the profiles generated by the computer analyses are shown in Fig. 20. In the hydrophilicity profile, deflection above the abscissa indicates hydrophilicity, and below the abscissa indicates hydrophobicity. The probability that a polypeptide region
30 is antigenic is usually considered to increase when there
35

5 is a deflection upward from the abscissa in the hydrophilic and/or antigenic profile. It should be noted, however, that these profiles are not necessarily indicators of the strength of the immunogenicity of a polypeptide.

Identification of Co-linear Peptides in HCV and Flaviviruses

10 The amino acid sequence of the putative polyprotein encoded in the HCV cDNA sense strand was compared with the known amino acid sequences of several members of Flaviviruses. The comparison shows that homology is slight, but due to the regions in which it is found, it is probably significant. The conserved co-linear regions are shown in Fig. 21. The amino acid numbers listed below the sequences represent the number in the putative HCV polyprotein (See Fig. 17.)

15 20 The spacing of these conserved motifs is similar between the Flaviviruses and HCV, and implies that there is some similarity between HCV and these flaviviral agents.

25 30 The following listed materials are on deposit under the terms of the Budapest Treaty with the American Type Culture Collection (ATCC), 12301 Parklawn Dr., Rockville, Maryland 20852, and have been assigned the following Accession Numbers.

<u>lambda-gt11</u>		<u>ATCC No.</u>	<u>Deposit Date</u>
	HCV cDNA library	40394	1 Dec. 1987
	clone 81	40388	17 Nov. 1987
5	clone 91	40389	17 Nov. 1987
	clone 1-2	40390	17 Nov. 1987
	clone 5-1-1	40391	18 Nov. 1987
	clone 12f	40514	10 Nov. 1988
	clone 35f	40511	10 Nov. 1988
10	clone 15e	40513	10 Nov. 1988
	clone K9-1	40512	10 Nov. 1988
	JSC 308	20879	5 May 1988
	pS356	67683	29 April 1988

15 In addition, the following deposits were made on 11 May 1989.

	<u>Strain</u>	<u>Linkers</u>	<u>ATCC No.</u>
20	D1210 (Cf1/5-1-1)	EF	67967
	D1210 (Cf1/81)	EF	67968
	D1210 (Cf1/CA74a)	EF	67969
	D1210 (Cf1/35f)	AB	67970
	D1210 (Cf1/279a)	EF	67971
25	D1210 (Cf1/C36)	CD	67972
	D1210 (Cf1/13i)	AB	67973
	D1210 (Cf1/C33b)	EF	67974
	D1210 (Cf1/CA290a)	AB	67975
	HB101 (AB24/C100 #3R)		67976

30 The following derivatives of strain D1210 were deposited on 3 May 1989.

	<u>Strain Derivative</u>	<u>ATCC No.</u>
5	pCF1CS/C8f	67956
	pCF1AB/C12f	67952
	pCF1EF/14c	67949
	pCF1EF/15e	67954
	pCF1AB/C25c	67958
10	pCF1EF/C33c	67953
	pCF1EF/C33f	67050
	pCF1CD/33g	67951
	pCF1CD/C39c	67955
	pCF1EF/C40b	67957
	pCF1EF/CA167b	67959

15 The following strains were deposited on May 12, 1989.

	<u>Strain</u>	<u>ATCC No.</u>
	Lambda gt11(C35)	40603
20	Lambda gt10(beta-5a)	40602
	D1210 (C40b)	67980
	D1210 (M16)	67981

Upon allowance and issuance of this application as a
25 United States Patent, all restriction on availability of
these deposits will be irrevocably removed; and access to
the designated deposits will be available during pendency
of the above-named application to one determined by the
Commissioner to be entitled thereto under 37 CFR 1.14 and
30 35 USC 1.22. Moreover, the designated deposits will be
maintained for a period of thirty (30) years from the date
of deposit, or for five (5) years after the last request
for the deposit; or for the enforceable life of the U.S.
35 patent, whichever is longer. The deposited materials
mentioned herein are intended for convenience only, and
are not required to practice the present invention in view

of the descriptions herein, and in addition these materials are incorporated herein by reference.

5

Industrial Applicability

The invention, in the various manifestations disclosed herein, has many industrial uses, some of which are the following. The HCV cDNAs may be used for the design of probes for the detection of HCV nucleic acids in samples. The probes derived from the cDNAs may be used to detect HCV nucleic acids in, for example, chemical synthetic reactions. They may also be used in screening programs for anti-viral agents, to determine the effect of the agents in inhibiting viral replication in cell culture systems, and animal model systems. The HCV polynucleotide probes are also useful in detecting viral nucleic acids in humans, and thus, may serve as a basis for diagnosis of HCV infections in humans.

20

In addition to the above, the cDNAs provided herein provide information and a means for synthesizing polypeptides containing epitopes of HCV. These polypeptides are useful in detecting antibodies to HCV antigens. A series of immunoassays for HCV infection, based on recombinant polypeptides containing HCV epitopes are described herein, and will find commercial use in diagnosing HCV induced NANBH, in screening blood bank donors for HCV-caused infectious hepatitis, and also for detecting contaminated blood from infectious blood donors. The viral antigens will also have utility in monitoring the efficacy of anti-viral agents in animal model systems. In addition, the polypeptides derived from the HCV cDNAs disclosed herein will have utility as vaccines for treatment of HCV infections.

30

The polypeptides derived from the HCV cDNAs, besides the above stated uses, are also useful for raising anti-HCV antibodies. Thus, they may be used in anti-HCV

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vaccines. However, the antibodies produced as a result of immunization with the HCV polypeptides are also useful in detecting the presence of viral antigens in samples. Thus, 5 they may be used to assay the production of HCV polypeptides in chemical systems. The anti-HCV antibodies may also be used to monitor the efficacy of anti-viral agents in screening programs where these agents are tested 10 in tissue culture systems. They may also be used for passive immunotherapy, and to diagnose HCV caused NANBH by allowing the detection of viral antigen(s) in both blood donors and recipients. Another important use for anti-HCV 15 antibodies is in affinity chromatography for the purification of virus and viral polypeptides. The purified virus and viral polypeptide preparations may be used in vaccines. However, the purified virus may also be useful for the development of cell culture systems in which HCV replicates.

20 Antisense polynucleotides may be used as inhibitors of viral replication.

For convenience, the anti-HCV antibodies and HCV polypeptides, whether natural or recombinant, may be packaged into kits.

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CLAIMS

- 5 1. A recombinant polynucleotide comprising a sequence derived from HCV cDNA, wherein the HCV cDNA is in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pi14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, or wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 10 8659 to 8866 in Fig. 17.
- 15 2. A recombinant polynucleotide according to claim 1, encoding an epitope of HCV.
- 15 3. A recombinant vector comprising the polynucleotide of claim 1 or claim 2.
- 20 4. A host cell transformed with the vector of claim 3.
- 25 5. A recombinant expression system comprising an open reading frame (ORF) of DNA derived from the recombinant polynucleotide of claim 1 or claim 2, wherein the ORF is operably linked to a control sequence compatible with a desired host.
- 30 6. A cell transformed with the recombinant expression system of claim 5.
- 35 7. A polypeptide produced by the cell of claim 6.
8. A purified polypeptide comprising an epitope encoded within HCV cDNA wherein the HCV cDNA is of a

sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17.

5

9. An immunogenic polypeptide produced by a cell transformed with a recombinant expression vector comprising an ORF of DNA derived from HCV cDNA, wherein the HCV cDNA is comprised of a sequence derived from the HCV cDNA sequence in clone CA279a, or clone CA74a, or clone 13i, or clone CA290a, or clone 33C or clone 40b, or clone 33b, or clone 25c, or clone 14c, or clone 8f, or clone 33f, or clone 33g, or clone 39c, or clone 15e, and wherein the ORF is operably linked to a control sequence compatible with a desired host.

15

10. A peptide comprising an HCV epitope, wherein the peptide is of the formula

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$$\text{AA}_x\text{-AA}_y$$

wherein x and y designate amino acid numbers shown in Fig. 17, and wherein the peptide is selected from the group consisting of AA1-AA25, AA1-AA50, AA1-AA84, AA9-AA177, AA1-AA10, AA5-AA20, AA20-AA25, AA35-AA45, AA50-AA100, AA40-AA90, AA45-AA65, AA65-AA75, AA80-90, AA99-AA120, AA95-AA110, AA105-AA120, AA100-AA150, AA150-AA200, AA155-AA170, AA190-AA210, AA200-AA250, AA220-AA240, AA245-AA265, AA250-AA300, AA290-AA330, AA290-305, AA300-AA350, AA310-AA330, AA350-AA400, AA380-AA395, AA405-AA495, AA400-AA450, AA405-AA415, AA415-AA425, AA425-AA435, AA437-AA582, AA450-AA500, AA440-AA460, AA460-AA470, AA475-AA495, AA500-AA550, AA511-AA690, AA515-AA550, AA550-AA600, AA550-AA625, AA575-AA605, AA585-AA600, AA600-AA650, AA600-AA625, AA635-AA665, AA650-AA700, AA645-AA680, AA700-AA750, AA700-AA725, AA700-AA750, AA725-AA775, AA770-AA790, AA750-AA800, AA800-AA815,

AA825-AA850, AA850-AA875, AA800-AA850, AA920-AA990,
AA850-AA900, AA920-AA945, AA940-AA965, AA970-AA990,
AA950-AA1000, AA1000-AA1060, AA1000-AA1025, AA1000-AA1050,
5 AA1025-AA1040, AA1040-AA1055, AA1075-AA1175,
AA1050-AA1200, AA1070-AA1100, AA1100-AA1130,
AA1140-AA1165, AA1192-AA1457, AA1195-AA1250,
AA1200-AA1225, AA1225-AA1250, AA1250-AA1300,
AA1260-AA1310, AA1260-AA1280, AA1266-AA1428,
10 AA1300-AA1350, AA1290-AA1310, AA1310-AA1340, AA1345-
AA1405, AA1345-AA1365, AA1350-AA1400, AA1365-AA1380,
AA1380-AA1405, AA1400-AA1450, AA1450-AA1500,
AA1460-AA1475, AA1475-AA1515, AA1475-AA1500,
AA1500-AA1550, AA1500-AA1515, AA1515-AA1550,
15 AA1550-AA1600, AA1545-AA1560, AA1569-AA1931,
AA1570-AA1590, AA1595-AA1610, AA1590-AA1650,
AA1610-AA1645, AA1650-AA1690, AA1685-AA1770,
AA1689-AA1805, AA1690-AA1720, AA1694-AA1735,
AA1720-AA1745, AA1745-AA1770, AA1750-AA1800,
20 AA1775-AA1810, AA1795-AA1850, AA1850-AA1900,
AA1900-AA1950, AA1900-AA1920, AA1916-AA2021,
AA1920-AA1940, AA1949-AA2124, AA1950-AA2000,
AA1950-AA1985, AA1980-AA2000, AA2000-AA2050,
AA2005-AA2025, AA2020-AA2045, AA2045-AA2100,
25 AA2045-AA2070, AA2054-AA2223, AA2070-AA2100,
AA2100-AA2150, AA2150-AA2200, AA2200-AA2250,
AA2200-AA2325, AA2250-AA2330, AA2255-AA2270,
AA2265-AA2280, AA2280-AA2290, AA2287-AA2385,
AA2300-AA2350, AA2290-AA2310, AA2310-AA2330,
30 AA2330-AA2350, AA2350-AA2400, AA2348-AA2464,
AA2345-AA2415, AA2345-AA2375, AA2370-AA2410,
AA2371-AA2502, AA2400-AA2450, AA2400-AA2425,
AA2415-AA2450, AA2445-AA2500, AA2445-AA2475,
AA2470-AA2490, AA2500-AA2550, AA2505-AA2540,
35 AA2535-AA2560, AA2550-AA2600, AA2560-AA2580,
AA2600-AA2650, AA2605-AA2620, AA2620-AA2650,

AA2640-AA2660, AA2650-AA2700, AA2655-AA2670,
AA2670-AA2700, AA2700-AA2750, AA2740-AA2760,
AA2750-AA2800, AA2755-AA2780,
5 AA2780-AA2830, AA2785-AA2810, AA2796-AA2886,
AA2810-AA2825, AA2800-AA2850, AA2850-AA2900,
AA2850-AA2865, AA2885-AA2905, AA2900-AA2950,
AA2910-AA2930, AA2925-AA2950, AA2945-end(C' terminal).

10 11. A polypeptide comprised of the peptide of
claim 10.

15 12. An immunogenic polypeptide attached to a
solid substrate, wherein the polypeptide is according to
claim 7, or claim 8, or claim 9, or claim 10, or claim 11,
or wherein the polypeptide is comprised of an epitope
encoded within HCV cDNA wherein the HCV cDNA is of a
sequence indicated by nucleotide numbers -319 to 1348 or
20 8659 to 8866 in Fig. 17.

25 13. A monoclonal antibody directed against an
epitope encoded in HCV cDNA, wherein the HCV cDNA is of a
sequence indicated by nucleotide numbers -319 to 1348 or
8659 to 8866 in Fig. 17, or is the sequence present in
clone 13i, or clone 26j, or clone 59a, or clone 84a, or
clone CA156e, or clone 167b, or clone pi14a, or clone
CA216a, or clone CA290a, or clone ag30a, or clone 205a, or
clone 18g, or clone 16jh.

30 14. A preparation of purified polyclonal anti-
bodies directed against a polypeptide comprised of an
epitope encoded within HCV cDNA, wherein the HCV cDNA is
of a sequence indicated by nucleotide numbers -319 to 1348
or 8659 to 8866 in Fig. 17, or is the sequence present in
35 clone 13i, or clone 26j, or clone 59a, or clone 84a, or
clone CA156e, or clone 167b, or clone pi14a, or clone

CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh.

5 15. A polynucleotide probe for HCV, wherein the probe is comprised of an HCV sequence derived from an HCV cDNA sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or from the complement of the HCV cDNA sequence.

10

16. A kit for analyzing samples for the presence of polynucleotides from HCV comprising a polynucleotide probe containing a nucleotide sequence of about 8 or more nucleotides, wherein the nucleotide sequence is derived from HCV cDNA which is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, wherein the polynucleotide probe is in a suitable container.

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17. A kit for analyzing samples for the presence of an HCV antigen comprising an antibody which reacts immunologically with an HCV antigen, wherein the antigen contains an epitope encoded within HCV cDNA which is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or wherein the HCV cDNA is in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone p114a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh.

30

18. A kit for analyzing samples for the presence of an HCV antibody comprising an antigenic polypeptide containing an HCV epitope encoded within HCV cDNA which is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is in clone 13i, or clone 26j, or clone 59a, or clone 84a, or

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clone CA156e, or clone 167b, or clone pi14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh.

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19. A kit for analyzing samples for the presence of an HCV antibody comprising an antigenic polypeptide expressed from HCV cDNA in clone CA279a, or clone CA74a, or clone 13i, or clone CA290a, or clone 33C or clone 40b, or clone 33b, or clone 25c, or clone 14c, or clone 8f, or clone 33f, or clone 33g, or clone 39c, or clone 15e, wherein the antigenic polypeptide is present in a suitable container.

15

20. A method for detecting HCV nucleic acids in a sample comprising:

(a) reacting nucleic acids of the sample with a polynucleotide probe for HCV, wherein the probe is comprised of an HCV sequence derived from an HCV cDNA sequence is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, and wherein the reacting is under conditions which allow the formation of a polynucleotide duplex between the probe and the HCV nucleic acid from the sample,

25 (b) detecting a polynucleotide duplex which contains the probe, formed in step (a).

30

21. An immunoassay for detecting an HCV antigen comprising:

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(a) incubating a sample suspected of containing an HCV antigen with an antibody directed against an HCV epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pi14a, or clone

5 CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, and wherein the incubating is under conditions which allow formation of an antigen-antibody complex; and (b) detecting an antibody-antigen complex formed in step (a) which contains the antibody.

10 22. An immunoassay for detecting antibodies directed against an HCV antigen comprising:

15 (a) incubating a sample suspected of containing anti-HCV antibodies with an antigen polypeptide containing an epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pil4a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, and wherein the incubating is under conditions which allow formation of an antigen-antibody complex; and

20 (b) detecting an antibody-antigen complex formed in step (a) which contains the antigen polypeptide.

25 23. An immunoassay for detecting antibodies directed against an HCV antigen comprising:

30 (a) incubating a sample suspected of containing anti-HCV antibodies with the polypeptide of claim 9, under conditions which allow formation of an antigen-antibody complex; and (b) detecting an antibody-antigen complex formed in step (a) which contains the antigen polypeptide.

35 24. A vaccine for treatment of HCV infection comprising an immunogenic polypeptide containing an HCV epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or

8659 to 8866 in Fig. 17 or is the sequence present in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone p14a, or clone 5
5 CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, and wherein the immunogenic polypeptide is present in a pharmacologically effective dose in a pharmaceutically acceptable excipient.

10 25. A method for producing antibodies to HCV comprising administering to an individual an isolated immunogenic polypeptide containing an HCV epitope encoded in HCV cDNA, wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, or is of the sequence present in clone CA279a, or clone CA74a, or clone 13i, or clone CA290a, or clone 33C or clone 40b, or clone 33b, or clone 25c, or clone 14c, or clone 8f, or clone 33f, or clone 33g, or clone 39c, or clone 15e, and wherein the immunogenic polypeptide is present in a pharmacologically effective dose in a pharmaceutically acceptable excipient.

15 26. An antisense polynucleotide derived from HCV cDNA, wherein the HCV cDNA is that shown in Fig. 17.

20 27. A method for preparing purified fusion polypeptide C100-3 comprising:

25 (a) providing a crude cell lysate containing polypeptide C100-3,

30 (b) treating the crude cell lysate with an amount of acetone which causes the polypeptide to precipitate,

35 (c) isolating and solubilizing the precipitated material,

(d) isolating the C100-3 polypeptide by anion exchange chromatography, and

(e) further isolating the C100-3 polypeptide of step (d) by gel filtration.

5

28. A method for preparing an HCV polypeptide comprising:

(a) providing a host cell transformed with a recombinant expression system comprising an open reading frame (ORF) of DNA derived from HCV cDNA, wherein the HCV cDNA is in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone p14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, or wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17, wherein the ORF is operably linked to a control sequence compatible with a desired host; and

(b) incubating the host cell under conditions which allow expression of the HCV polypeptide.

20 29. A method for preparing an immunogenic HCV polypeptide comprising:

(a) providing a host cell transformed with a recombinant expression vector comprising an ORF of DNA derived from HCV cDNA, wherein the HCV cDNA is comprised of a sequence derived from the HCV cDNA sequence in clone CA279a, or clone CA74a, or clone 13i, or clone CA290a, or clone 33c, or clone 40b, or clone 33b, or clone 25c, or clone 14c, or clone 8f, or clone 33f, or clone 33g, or clone 39c, or clone 15e, wherein the ORF is operably linked to a control sequence compatible with the desired host; and

35 (b) incubating the host cell under conditions which allow expression of the HCV polypeptide.

30. A method for preparing a host cell

transformed with a recombinant polynucleotide comprising a sequence of HCV cDNA derived from the HCV cDNA in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone 5
CA156e, or clone 167b, or clone p14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, or wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17 comprising:

- 10 (a) providing a host cell capable of transformation;
- 15 (b) providing the recombinant polynucleotide; and
- (c) incubating (a) with (b) under conditions which allow transformation of the host cell with the polynucleotide.

31. A method for preparing a recombinant polynucleotide comprised of a sequence of HCV cDNA derived from the HCV cDNA in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone p14a, or clone CA216a, or clone CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, or wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17 comprising:

- 20 (a) providing a host cell transformed with the recombinant polynucleotide; and
- 25 (b) isolating said polynucleotide from said host cell.

32. A method for preparing blood free of HCV comprising:

- 35 (a) providing a sample of blood suspected of containing HCV and anti-HCV antibodies;

(b) providing an immunogenic polypeptide prepared according to claim 28 or 29;

5 (c) incubating the sample of (a) with the immunogenic polypeptide of (b) under conditions which allow the formation of antibody-HCV polypeptide complexes;

(d) detecting the complexes formed in step (c); and

10 (e) saving the blood from which complexes were not detected in (d).

33. A method for preparing blood free of HCV comprising:

15 (a) providing nucleic acids from a sample of blood suspected of containing HCV polynucleotides;

(b) providing a probe for HCV, wherein the probe is comprised of an HCV sequence derived from an HCV cDNA which is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17,

20 (c) reacting (a) with (b) under conditions which allow the formation of a polynucleotide duplex between the probe and the HCV nucleic acid from the sample;

(d) detecting a polynucleotide which contains the probe, formed in step (c); and

25 (e) saving the blood from which complexes were not detected in (d).

30 34. A method for producing a hybridoma which produces anti-HCV monoclonal antibodies comprising:

(a) immunizing an individual with an immunogenic polypeptide containing an epitope encoded in HCV cDNA, wherein the HCV cDNA is HCV cDNA in clone 13i, or clone 26j, or clone 59a, or clone 84a, or clone CA156e, or clone 167b, or clone pil4a, or clone CA216a, or clone

5 CA290a, or clone ag30a, or clone 205a, or clone 18g, or clone 16jh, or wherein the HCV cDNA is of a sequence indicated by nucleotide numbers -319 to 1348 or 8659 to 8866 in Fig. 17; or

(b) immunizing an individual with an immunogenic polypeptide prepared according to claim 29;

(c) immortalizing antibody producing cells from the immunized individual;

10 (d) selecting an immortal cell which produces antibodies which react with an HCV epitope in the immunogenic polypeptide of (a) or (b); and

(e) growing said immortal cell.

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FIG. | Translation of DNA 12f

IlePheLysIleArgMetTyrValGlyGlyValGluHisArgLeuGluAlaAlaCysAsn

1 CCATATTTAAATCAGGATGTACGTGGGAGGGGTCGAACACAGGCTGGAAGCTGCCTGCA
GGTATAAATTTAGTCCTACATGCACCCCTCCCCAGCTTGTGTCGACCTTCGACGGACGT

TrpThrArgGlyGluArgCysAspLeuGluAspArgAspArgSerGluLeuSerProLeu

61 ACTGGACCGCGGGCGAACGTTGCGATCTGGAAGACAGGGACAGGTCCGAGCTCAGCCCGT
TGACCTGCGCCCCGCTTGCAACGCTAGACCTTCTGTCCTGTCAGGCTCGAGTCGGGCA

LeuLeuThrThrThrGlnTrpGlnValLeuProCysSerPheThrThrLeuProAlaLeu

121 TACTGCTGACCACTACACAGTGGCAGGTCCCTCCGTGTTCCCTCACAAACCCCTACCAGCCT
ATGACGACTGGTGATGTGTCACCGTCCAGGAGGGCACAAGGAAGTGGTGGGATGGTCGGA

SerThrGlyLeuIleHisLeuHisGlnAsnIleValAspValGlnTyrLeuTyrGlyVal

181 TGTCCACCGGCCTCATCCACCTCCACCAGAACATTGTGGACGTGCAGTACTTGTACGGGG
ACAGGTGGCCGGAGTAGGTGGAGGTCTTGTAAACACCTGCACGTATGAACATGCC

GlySerSerIleAlaSerTrpAlaIleLysTrpGluTyrValValLeuLeuPheLeuLeu

241 TGGGGTCAAGCATCGCGCCTGGGCATTAAGTGGAGTACGTGTTCTGTCCTGTCCTTC
ACCCCAGTTCGTAGCGCAGGACCCGTAATTCACCCCTATGCAGCAAGAGGACAAGGAAG

LeuAlaAspAlaArgValCysSerCysLeuTrpMetMetLeuLeuIleSerGlnAlaGlu

301 TGCTTGCAGACCGCGCGTCTGCTCCTGCTTGTGGATGATGCTACTCATATCCAAGCGG
ACGAACGTCTGCGCGCAGACGAGGACGAACACCTACTACGATGAGTATAGGGTTCGCC

AlaAlaLeuGluAsnLeuValIleLeuAsnAlaAlaSerLeuAlaGlyThrHisGlyLeu

361 AGGCGGTTGGAGAACCTCGTAATACTTAATGCAGCATCCCTGGCCGGGACGCACGGTC
TCCGCCAACCTCTGGAGCATTATGAATTACGTCGTAGGGACCAGGCCCTGCGTGCCAG

Val

421 TTGTATC
AACATAG

FIG. 2-I Translation of DNA k9-1

GlyCysProGluArgLeuAlaSerCysArgProLeuThrAspPheAspGlnGlyTrpGly
 1 CAGGCTGTCCTGAGAGGCTAGCCAGCTGCCGACCCCTAACGATTGACCAAGGGCTGGG
 GTCCGACAGGACTCTCGATCGTCGACGGCTGGGAATGGCTAAACTGGTCCCACCC

 ProIleSerTyrAlaAsnGlySerGlyProAspGlnArgProTyrCysTrpHisTyrPro
 61 GCCTATCAGTTATGCCAACCGAACGGCCCGACCAGCGCCCTACTGCTGGCACTACC
 CGGGATAGTCATAACGGTGCCTCGCCGGGCTGGTCGCGGGGATGACGACCGTGATGG

 ProLysProCysGlyIleValProAlaLysSerValCysGlyProValTyrCysPheThr
 121 CCCCAAAACCTTGCGGTATTGTGCCCGCGAACGAGGTGTGTGGTCCGGTATATTGCTTC
 GGGGTTTGGAACGCCATAACACGGCGCTCTCACACACACCAGGCCATATAACGAAGT

 ProSerProValValValGlyThrThrAspArgSerGlyAlaProThrTyrSerTrpGly
 181 CTCCCAGCCCCGTGGTGGGGAACGACCGACAGGTGCGGCCACCTACAGCTGGG
 GAGGGTCGGGGCACCAACACCCTGCTGGCTGCCAGCCGCGGGTGGATGTCGACCC

 GluAsnAspThrAspValPheValLeuAsnAsnThrArgProProLeuGlyAsnTrpPhe
 241 GTGAAAATGATACGGACGTCTCGCTTAACAATACCAGGCCACCGCTGGGCAATTGGT
 CACTTTACTATGCCTGCAGAACAGGAAATTGTTATGGTCCGGTGGCGACCCGTTAACCA

 GlyCysThrTrpMetAsnSerThrGlyPheThrLysValCysGlyAlaProProCysVal
 301 TCGGTTGTACCTGGATGAACACTGATTACCAAAGTGTGGAGCGCCTCTTG
 AGCCAACATGGACCTACTTGAGTTGACCTAACAGCCTCGCGAGGAACAC

 IleGlyGlyAlaGlyAsnAsnThrLeuHisCysProThrAspCysPheArgLysHisPro
 361 TCATCGGAGGGGCGGGCAACAAACACCCCTGCACTGCCACTGATTGCTCCGCAAGC
 AGTAGCCTCCCCGCCGTGTTGTCGGGACGTGACGGGTGACTAACGAAGGCGTTCTAG

 AspAlaThrTyrSerArgCysGlySerGlyProTrpIleThrProArgCysLeuValAsp
 421 CGGACGCCACATACTCTCGGTGCCCTCCGGATCACACCCAGGTGCCCTGGTCG
 GCCTGCGGTGTATGAGAGGCCACGCCAGGGACCTAGTGTGGTCCACGGACCA

 TyrProTyrArgLeuTrpHisTyrProCysThrIleAsnTyrThrIlePheLysIleArg
 481 ACTACCCGTATAGGCTTGGCATTATCCTGTACCATCAACTACACTATTTAAAATCA
 TGATGGCATATCGAAACCGTAATAGGAACATGGTAGTTGATGTGATATAAATTAGT

 MetTyrValGlyGlyValGluHisArgLeuGluAlaAlaCysAsnTrpThrArgGlyGlu
 541 GGATGTACGTGGGAGGGGTCGAGCACAGGCTGGAAGCTGCCACTGGACGCCGGCG
 CCTACATGCACCCCTCCCCAGCTCGTGTCCGACCTCGACGGACGTTGACCTGCGCCCGC

 ArgCysAspLeuGluAspArgAspArgSerGluLeuSerProLeuLeuLeuThrThr
 601 AACGTTGCGATCTGGAAAGATAGGGACAGGTCCGAGCTCAGCCGTTACTGCTGACCA
 TTGCAACGCTAGACCTCTATCCCTGTCCAGGCTCGAGTCGGCAATGACGACTGGTGAT

 GlnTrpGlnValLeuProCysSerPheThrThrLeuProAlaLeuSerThrGlyLeuIle
 661 CACAGTGGCAGGTCCCTCCGTGTTCTCACACCCCTGCCAGCCTTGCCACCGGCCTCA
 GTGTACCGTCCAGGAGGGCACAAGGAAGTGTGGGACGGTCGGAACAGGTGGCCGGAGT

 HisLeuHisGlnAsnIleValAspValGlnTyrLeuTyrGlyValGlySerSerIleAla
 721 TCCACCTCCACCAGAACATTGTGGACGTGCAGTACTTGTACGGGGTGGGTCAAGCATCG
 AGGTGGAGGTGGTCTTGTAAACACCTGCACGTCACTGAACATGCCCAACCCAGTTCTAGC

 SerTrpAlaIleLysTrpGluTyrValValLeuLeuPheLeuLeuAlaAspAlaArg
 781 CGTCCTGGGCCATTAAGTGGGAGTACGTGCGCTCTCTGCTTGCTGAGACGCGC
 GCAGGACCGGTAATTCACCCCTCATGCAGCAGGAGGACAAGGAAGACGAACGACTGCGCG

841 ValCysSerCysLeuTrpMetMetLeuLeuIleSerGlnAlaGluAlaAlaLeuGluAsn
GCGTCTGCTCCTGCTTGTGGATGATGCTACTCATATCCAAGCGGAAGCGGCTTGGAGA
CGCAGACGAGGACGAACACCTACTACGATGAGTATAGGGTTCGCCCTCGCCGAAACCTCT

901 LeuValIleLeuAsnAlaAlaSerLeuAlaGlyThrHisGlyLeuValSerPheLeuVal
ACCTCGTAATACTTAATGCAGCATCCCTGGCCGGACGCACGGTCTTGTATCCTTCCTCG
TGGAGCATTATGAATTACGTCGTAGGGACCAGGCCCTGCGTGCAGAACATAGGAAGGAGC

961 PhePheCysPheAlaTrpTyrLeuLysGlyLysTrpValProGlyAlaValTyrThrPhe
TGTCTCTGCTTGCATGGTATCTGAAGGGTAAGTGGTGCCTGGAGCGGCTACACCT
ACAAGAACGAAACGTACCATAGACTTCCCATTACCCACGGGCCTGCCAGATGTGGA

1021 TyrGlyMetTrpProLeuLeuLeuLeuAlaLeuProGlnArgAlaTyrAlaLeu
TCTACGGGATGTGGCCTCTCCTCGCTCTGGCTTGGCGTTGCCCGAGCGGCTACGCGC
AGATGCCCTACACCGGAGAGGAGGACGAGGACAACCGAACAGAGCAGCCAACTACCGCGATT

1081 AspThrGluValAlaAlaSerCysGlyGlyValValLeuValGlyLeuMetAlaLeuThr
TGGACACGGAGGTGGCCGCGTCGTGTCGGCGTTCTCGTCGGGTTGATGGCGCTAA
ACCTGTGCCTCCACCGGCGCAGCACACCGCACAACAAGAGCAGCCAACTACCGCGATT

1141 LeuSerProTyrTyrLysArgTyrIleSerTrpCysLeuTrpTrpLeuGlnTyrPheLeu
CTCTGTCACCATATTACAAGCGCTATATCAGCTGGTCTTGTGGCTTCAGTATTTTC
GAGACAGTGGTATAATGTCGCGATATAGTCGACCACGAACACCACCGAAGTCATAAAAG

1201 ThrArgValGluAlaGlnLeuHisValTrpIleProProLeuAsnValArgGlyGlyArg
TGACCAGAGTGGAAAGCGCAACTGCACGTGTGGATTCCCCCCTCAACGTCCGAGGGGGGC
ACTGGTCTCACCTTCGCGTTGACGTGACACCTAACGGGGGAGTTGCAGGCTCCCCCG

1261 AspAlaValIleLeuLeuMetCysAlaValHisProThrLeuValPheAspIleThrLys
GCGACGCTGTCATCTTACTCATGTGTGCTGTACACCCGACTCTGGTATTGACATCACCA
CGCTGCGACAGTAGAACATGAGTACACACGACATGTGGGCTGAGACCATAAAACTGTAGTGGT

1321 LeuLeuLeuAlaValPheGlyProLeuTrpIleLeuGlnAla
AATTGCTGCTGGCCGTCCTCGGACCCCTTGGATTCTCAAGCCAG
TTAACGACGACCGGCAGAACGCTGGGAAACCTAACAGTTCGGTC

FIG. 2-2

FIG. 3

1 GlyAlaGlyLysArgValTyrTyrLeuThrArgAspProThrThrProLeuAlaArgAla
 CGGCGCTGGAAAGAGGGTCACTACCTCACCCGTGACCCATACAACCCCCCTCGCGAGAGC
 GCCCGCACCTTCTCCCAGATGGAGTGGGACTGGGATGTTGGGGAGCGCTCTCG

 61 AlaTrpGluThrAlaArgHisThrProValAsnSerTrpLeuGlyAsnIleIleMetPhe
 TGCCTGGGAGACAGCAAGACACACTCAGTCAGTCAATTCTGGTAGGCAACATAATCATGTT
 ACGCACCCCTCTGTCGTTGTGAGGTCAAGTAAGGACCGATCCGTGTATTAGTACAA

 121 AlaProThrLeuTrpAlaArgMetIleLeuMetThrHisPhePheSerValLeuIleAla
 TGCCCCCACACTGTGGCGAGGATGATACTGATGACCCATTCTTAGCGTCCTTATAGC
 ACGGGGGTGTGACACCCGCTCCTACTATGACTACTGGTAAAGAAATCGCAGGAATATCG

 181 ArgAspGlnLeuGluGlnAlaLeuAspCysGluIleTyrGlyAlaCysTyrSerIleGlu
 CAGGGACCAGCTTGAACAGGCCCTCGATTGCGAGATCTACGGGGCCTGCTACTCCATAGA
 GTCCCTGGTCGAACTTGTCCGGGAGCTAACGCTCTAGATGCCCGGACGATGAGGTATCT

 241 ProLeuAspLeuProProIleIleGlnArgLeu
 ACCACTTGATCTACCTCCAATCATTCAAAGACTC
 TGGTGAACTAGATGGAGGTAGTAAGTTCTGAG

FIG. 5

Translation of DNA 26j

1 LeuPheTyrHisHisLysPheAsnSerSerGlyCysProGluArgLeuAlaSerCysArg
 GCTTTCTATCACCAACAAGTCAACTCTCAGGCTGTCCTGAGAGGCTAGCCAGCTGCCG
 CGAAAAGATAGTGGTGTCAAGTTGAGAAGTCCGACAGGACTCTCGATCGTCGACGGC

 61 ProLeuThrAspPheAspGlnGlyTrpGlyProIleSerTyrAlaAsnGlySerGlyPro
 ACCCCTTACCGATTGACCAAGGGCTGGGGCCCTATCAGTTATGCCAACGGAAAGCGGCC
 TGGGAATGGCTAAACTGGTCCCGACCCCGGGATAGTCAATACGGTTGCCCTCGCCGGG

 121 AspGlnArgProTyrCysTrpHisTyrProProLysProCysGlyIleValProAlaLys
 CGACCAGCGCCCCTACTGCTGGCACTACCCCCAAAACCTTGCCTATTGTGCCCGCGAA
 GCTGGTCGCGGGGATGACGACCGTGATGGGGGTTTGGAACGCCATAACACGGCGCTT

 181 ---Overlap with 131---
 SerValCysGlyProValTyrCysPheThrProSerProValValVal
 GAGTGTGTGGTCCGGTATATTGCTTCACTCCCAGCCCGTGGTGGTGG
 CTCACACACACCAGGCCATATAACGAAGTGAGGGTCGGGCACCACCC

FIG. 4

Translation of DNA 13i

1 ProSerProValValValGlyThrThrAspArgSerGlyAlaProThrTyrSerTrpGly
 CTCCCAGCCCCGTGGTGGTGGAAACGACCGACAGGTCGGCGCGCCTACCTACAGCTGGG
 GAGGGTCGGGGCACCAACCACCTTGCTGGCTGTCCAGCCCAGCGCGGATGGATGTCGACCC

61 GluAsnAspThrAspValPheValLeuAsnAsnThrArgProProLeuGlyAsnTrpPhe
 GTGAAAATGATAACGGACGTCTCGTCCTAACAAATACCAAGGCCACCGCTGGGCAATTGGT
 CACTTTACTATGCCTGCAGAACAGGAATTGTTATGGTCCGGTGGCACCCTTAACCA

121 GlyCysThrTrpMetAsnSerThrGlyPheThrLysValCysGlyAlaProProCysVal
 TCGGGTGTACCTGGATGAACTCAACTGGATTACCAAAAGTGTGCGGAGCGCCTCCTGTG
 AGCCAACATGGACCTACTTGAGTTGACCTAACAGCCTCGCGAGGAACAC

181 IleGlyGlyAlaGlyAsnAsnThrLeuHisCysProThrAspCysPheArgLysHisPro
 TCATCGGAGGGGGCGGGCAACAAACACCCCTGCACTGCCCACTGATTGCTTCCGCAAGCATT
 AGTAGCCTCCCCGCCGTGTTGTGGGACGTGACGGGTGACTAACGAAGGCGTTCTAG

241 AspAlaThrTyrSerArgCysGlySerGlyProTrpLeuThrProArgCysLeuValAsp
 CGGACGCCACATACTCTCGGTGCGGCTCCGGCTGGCTCACACCCAGGTGCCTGGTCG
 GCCTGCGGTGTATGAGAGGCCACGCCAGGGACCGAGTGTGGGTCCACGGGACCAGC

301 TyrProTyrArgLeuTrpHisTyrProCysThrIleAsnTyrThrIlePheLysIleArg
 ACTACCCGTATAAGCTTGGCATTATCCTGTACCATCAACTACACCATAATTAAAATCA
 TGATGGGCATATCCGAAACCGTAATAGGAACATGGTAGTTGATGTGGTATAAATTAGT

361 MetTyrValGlyGlyValGluHisArgLeuGluAlaAlaCysAsnTrpThrArgGlyGlu
 GGATGTACGTGGGAGGGGTCGAGCACAGGCTGGAAGCTGCCTGCAACTGGACGCCGGCG
 CCTACATGCACCCCTCCCCAGCTGTCCGACCTTCGACGGACGTTGACCTGCGCCCGC

421 Overlap with 12f-
 ArgCysAspLeuGluAspArgAspArgSerGluLeuSerProLeuLeuLeuThrThrThr
 AACGTTGCGATCTGGAAAGACAGGGACAGGTCCGAGCTCAGCCCGTACTGCTGACCACTA
 TTGCAACGCTAGACCTTCTGTCCCTGTCCAGGCTCGAGTCGGGCAATGACGACTGGTGAT

481 GlnTrpGlnValLeuProCysSerPheThrThrLeuProAlaLeuSerThrGlyLeu
 CACAGTGGCAGGTCTCCCGTGTCTTCACAACCCCTGCCAGCCTGTCCACCGGCCTCA
 GTGTCACCGTCCAGGAGGGCACAGGAAGTGTGGGACGGTCGAAACAGGTGCCGGAGT

FIG. 6

Translation of DNA CA59a

1 LeuValMetAlaGlnLeuLeuArgIleProGlnAlaIleLeuAspMetIleAlaGlyAla
 TTGGTAAATGGCTCAGCTGCTCCGGATCCCACAAGCCATCTGGACATGATCGCTGGTGCT
 AACCATTACCGAGTCGACGAGGCCTAGGGTGTTGGTAGAACCTGTACTAGCGACCACGA

61 HisTrpGlyValLeuAlaGlyIleAlaTyrPheSerMetValGlyAsnTrpAlaLysVal
 CACTGGGGAGTCCTGGCGGGCATAGCGTATTCTCCATGGGGAACTGGGCGAAGGTC
 GTGACCCCTCAGGACCGCCCGTATCGATAAAGAGGTACCACCCCTTGACCCGCTTCCAG

121 LeuValValLeuLeuLeuPheAlaGlyValAspAlaGluThrHisValThrGlyGlySer
 CTGGTAGTGCTGCTGCTATTGCGCGCGTCGACCGGGAAACCCACGTCACCGGGGGAAAGT
 GACCATCACGACGACGATAAACGGCCGCAGCTGCGCTTGGGTGCAGTGGCCCCCTTCA

181 AlaGlyHisThrValSerGlyPheValSerLeuLeuAlaProGlyAlaLysGlnAsnVal
 GCCGGGCCACACTGTGCTGGATTGTTAGCCTCTCGCACCGGCCAACGAGCAGTC
 CGGCCGGTGTGACACAGACCTAAACAATCGGAGGAGCGTGTTCCGGTCTGCTTGCAG

241 GlnLeuIleAsnThrAsnGlySerTrpHisLeuAsnSerThrAlaLeuAsnCysAsnAsp
 CAGCTGATCAACACCAACGGCAGTTGGCACCTCAATAGCACGGCCCTGAACCTGCAATGAT
 GTCGACTAGTTGGTTGCCGTCAACCGTGGAGTTATCGTGCCGGACTTGACGTTACTA

301 SerLeuAsnThrGlyTrpLeuAlaGlyLeuPheTyrHisHisLysPheAsnSerSerGly
 AGCCTCAACACCGGCTGGTGGCAGGGCTTCTATCACCACAAGTCAACTCTTCAGGC
 TCGGAGTTGTGGCCGACCAACCGTCCGAAAAGATAGTGGTGTCAAGTTGAGAAGTCCG
 -----Overlap with 26j-----

-----Overlap with K9-1-----

361 CysProGluArgLeuAlaSerCysArgPro
 TGTCCTGAGAGGGCTAGCCAGCTGCCGACCCC
 ACAGGACTCTCCGATCGGTCGACGGCTGGGG

Translation of DNA CA84a

FIG. 7

1 GlnGlyCysAsnCysSerIleTyrProGlyHisIleThrGlyHisArgMetAlaTrpAsp
 CGCAAGGTTGCAATTGCTCTATCTATCCCGGCCATATAACGGGTACCGCATGGCATGGG
 GCGTCCAACGTTAACGAGATAGATAAGGGCCGGTATATTGCCAGTGGCGTACCGTACCC

61 MetMetMetAsnTrpSerProThrThrAlaLeuValMetAlaGlnLeuLeuArgIlePro
 ATATGATGATGAACTGGTCCCCTACGACGGCGTTGGTAATGGCTAGCTGCTCCGGATCC
 TATACTACTTGACCAGGGATGCTGCCGCAACCATTACCGAGTCGACGAGGCCTAGG

121 GlnAlaIleLeuAspMetIleAlaGlyAlaHisTrpGlyValLeuAlaGlyIleAlaTyr
 CACAAGCCATCTTGGACATGATCGCTGGTCACTGGGGAGTCCTGGCGGGCATAGCGT
 GTGTTGGTAGAACCTGTACTAGCGACCACGAGTGACCCCTCAGGACCGCCGTATCGCA

-----Overlap with CA59a-----

181 PheSerMetValGlyAsnTrpAlaLysValLeuValValLeuLeuPheAlaGlyVal
 ATTCTCCATGGTGGGGAACTGGCGAAGGTCTGGTAGTGCTGCTGCTATTGCCGGCG
 TAAAGAGGTACCACCCCTTGACCCGCTTCCAGGACCATCACGACGACGATAAACGGCCGC

241 AspAlaGluThrHisValThrGly
 TCGACGCGGAAACCCACGTCAACCGGG
 AGCTGCGCCTTGGGTGCAGTGGCCCC

Translation of DNA CA156e

FIG. 8

1 CysTrpValAlaMetThrProThrValAlaThrArgAspGlyLysLeuProAlaThrGln
 GTGTTGGGTGGCGATGACCCCTACGGTGGCCACCAGGGATGGCAAACCTCCCGCGACGCA
 CACAACCCACCGCTACTGGGATGCCACCGGTGGTCCCTACGTTGAGGGCGCTGCGT

61 LeuArgArgHisIleAspLeuLeuValGlySerAlaThrLeuCysSerAlaLeuTyrVal
 GCTCGACGTACATCGATCTGCTTGTGGAGCGCCACCCCTGTTGGCCCTCTACGT
 CGAAGCTGCAGTGTAGCTAGACGAAACAGCCCTCGCGTGGGAGACAAGCCGGAGATGCA

121 GlyAspLeuCysGlySerValPheLeuValGlyGlnLeuPheThrPheSerProArgArg
 GGGGGACCTATGCGGGTCTGTCTTCTGTCGGCCAACGTTCACCTCTCCCAGGCG
 CCCCTGGATACGCCCAGACAGAAACAGCCGGTGGACAAGTGGAAAGAGAGGGTCCGC

181 HisTrpThrThrGlnGlyCysAsnCysSerIleTyrProGlyHisIleThrGlyHisArg
 CCACTGGACGACGCAAGGTTGCAATTGCTCTATCTATCCCGGCCATATAACGGGTACCG
 GGTGACCTGCTGCGTCCAACGTTAACGAGATAGATAAGGGCCGGTATATTGCCAGTGGC

-----Overlap with CA84a-----

241 MetAlaTrpAspMetMetAsnTrpSerProThrThrAlaLeuValValAlaGlnLeu
 CATGGCATGGATATGATGATGAACTGGTCCCCTACGACGGCGTTGGTAGTGGCTCAGCT
 GTACCGTACCCCTATACTACTTGACCAGGGATGCTGCCGCAACCATACCGAGTCGA

301 LeuArgIleProGlnAla
 GCTCCGGATCCCACAAGCC
 CGAGGCCTAGGGTGGCG

FIG. 9

Translation of DNA CA167b

1 SerThrGlyLeuTyrHisValThrAsnAspCysProAsnSerSerIleValTyrGluAla
CTCCACGGGGCTTACCACTGACCGTACCAATGATTGCCCTAACTCGAGTATTGTGTACGAGGC
GAGGTGCCCGAAATGGTGCAGTGGTTACTAACGGGATTGAGCTATAACACATGCTCCG

61 AlaAspAlaIleLeuHisThrProGlyCysValProCysValArgGluGlyAsnAlaSer
GGCCGATGCCATCCTGCACACTCCGGGTGCGTCCCTGCGTTGAGGGCAACGCC
CCGGCTACGGTAGGACGTGTGAGGCCACGCAGGGACGCAAGCAACTCCGTTGCGGAG

121 ArgCysTrpValAlaMetThrProThrValAlaThrArgAspGlyLysLeuProAlaThr
GAGGTGTTGGGTGGCGATGACCCCTACGGTGGCCACCAGGGATGCCAAACTCCCCGCGAC
CTCCACAACCCACCGCTACTGGGATGCCACCGGTGGTCCCTACCGTTGAGGGCGCTG

181 -----Overlap with CA156e-----
GlnLeuArgArgHisIleAspLeuLeuValGlySerAlaThrLeuCysSerAlaLeuTyr
GCAGCTTCGACGTCACATCGATCTGCTTGTGCGGAGCGCTACCCCTGTTGGCCCTCTA
CGTCGAAGCTGCAGTGTAGCTAGACGAACAGCCCTCGCGATGGGAGACAAGCCGGGAGAT

241 -----
ValGlyAspLeuCysGlySerValPheLeu
CGTGGGGACTTGTGCAGGTCTGTCTTCTTG
GCACCCCTGAACACGCCAGACAGAAAGAAC

FIG. 10

Translation of DNA ssCA216a

1 ArgArgArgSerArgAsnLeuGlyLysValIleAspThrLeuThrCysGlyPheAlaAsp
 CCCGGCGTAGGTGCGCAATTGGGTAAGGTACATCGATAACCTTACGTGCGGCTTCGCCG
 GGGCCGCATCCAGCGCTTAAACCCATTCCAGTAGCTATGGGAATGCACGCCAAGCGGC

 61 LeuMetGlyTyrIleProLeuValGlyAlaProLeuGlyGlyAlaAlaArgAlaLeuAla
 ACCTCATGGGGTACATACCCTCGTCGGGCCCTTGGAGGCCTGCCAGGGCCCTGG
 TGGAGTACCCATGTATGGCGAGCAGCCGGGAGAACCTCCGCGACGGTCCCAGGACC

 121 HisGlyValArgValLeuGluAspGlyValAsnTyrAlaThrGlyAsnLeuProGlyCys
 CGCATGGCGTCCGGGTTCTGGAAGACGGCGTGAACATATGCAACAGGGAACCTCCTGGTT
 GCGTACCGCAGGCCAAGACCTCTGCCGACTTGATACGTTGCTCCCTGGAAAGGACCAA

 181 SerPheSerIlePheLeuLeuAlaLeuLeuSerCysLeuThrValProAlaSerAlaTyr
 GCTCTTCTCTATCTCCTCTGGCCCTGCTCTTGCTTGACTGTGCCCGCTTCGGCCT
 CGAGAAAGAGATAGAAGGAAGACCGGGACGAGAGAACGAACTGACACGGCGAAGCCGGA

 241 GlnValArgAsnSerThrGlyLeuTyrHisValThrAsnAspCysProAsnSerSerIle
 ACCAAAGTGCACACTCCACGGGCTTACCGTCACCAATGATTGCCCTAACCGAGTA
 TGGTTCACCGCTTGAGGTGCCGAAATGGTGCAGTGGTTACTAACGGGATTGAGCTCAT

 301 overlap with CA167b
 ValTyrGluAlaAlaAspAlaIleLeuHisThrProGlyCysValProCysValArgGlu
 TTGTGTACGAAGCGGCCGATGCCATCCTGCACACTCCGGGTGCGTCCCTGCGTTCTG
 AACACATGCTTCGCCGGCTACGGTAGGTGAGGCCCCACGCAGGGAACGCAAGCAC

 361 GlyAsnAlaSerArgCysTrpValAlaMetThrProThrValAla
 AGGGCAACGCCCTCGAGGTGTTGGGTGGCGATGACCCCTACGGTGGCC
 TCCCGTTGCGGAGCTCCACAACCCACCGCTACTGGGATGCCACCGG

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FIG. 11

Translation of DNA ssCA290a

1 LysLysAsnLysArgAsnThrAsnArgArgProGlnAspValLysPheProGlyGlyGly
 AAAAAAAAACAAACGTAACACCAACCGTCGCCACAGGACGTCAAGTTCCCGGGTGGCG
 TTTTTTTTTGTTGCATTGTGGTTGGCAGCGGGTGTCTGCAGTTCAAGGGCCCACCGC

61 GlnIleValGlyGlyValTyrLeuLeuProArgArgGlyProArgLeuGlyValArgAla
 GTCAGATCGTGGTGGAGTTACTTGTGCGCGCAGGGGCCCTAGATTGGGTGTGCGCG
 CAGTCTAGCAACCACCTCAAATGAACAAACGGCGCTCCCCGGATCTAACCCACACGCGC

121 ThrArgLysThrSerGluArgSerGlnProArgGlyArgArgGlnProIleProLysAla
 CGACGAGAAAGACTTCCGAGCGGTCGCAACCTCGAGGTAGACGCCAGCCTATCCCCAAGG
 GCTGCTCTTCTGAAGGCTGCCAGCGTTGGAGCTCCATCTCGGGTCGGATAGGGTTCC

181 ArgArgProGluGlyArgThrTrpAlaGlnProGlyTyrProTrpProLeuTyrGlyAsn
 CTCGTCGGCCCGAGGGCAGGACCTGGGCTCAGCCCCGGGTACCCCTGGCCCTCTATGGCA
 GAGCAGCCGGGCTCCCGTCCCTGGACCCGAGTCGGGCCATGGGAACCGGGGAGATACCGT

241 GluGlyCysGlyTrpAlaGlyTrpLeuLeuSerProArgGlySerArgProSerTrpGly
 ATGAGGGCTGCGGGTGGCGGGATGGCTCTGTCTCCCCTGGCTCTCGGGCTAGCTGGG
 TACTCCCGACGCCACCCGCCCTACCGAGGACAGAGGGCACCGAGAGCCGGATCGACCC

301 ProThrAspProArgArgSerArgAsnLeuGlyLysValIleAspThrLeuThrCys
 GCCCCACAGACCCCCGGCGTAGGTGCGCAATTGGGTAAGGTATCGATACCTTACGT
 CGGGGTGTCGGGGGCCGATCCAGCGCTTAAACCCATTCCAGTAGCTATGGGAATGCA

361 GlyPheAlaAspLeuMetGlyTyrIleProLeuValGlyAlaProLeuGlyGlyAlaAla
 GCGGCTTCGCCGACCTCATGGGTACATACCGCTCGTGGCGCCCTCTGGAGGCGCTG
 CGCCGAAGCGGCTGGAGTACCCCATGTATGGCGAGCAGCCGCGGGGAGAACCTCCGCGAC

overlap with CA216a

421 ArgAlaLeuAlaHisGlyValArgValLeuGluAspGlyValAsnTyrAlaThrGlyAsn
 CCAGGGCCCTGGCGCATGGCGTCCGGTTCTGGAAAGACGGCGTGAACATGCAACAGGGAA
 GGTCCCAGGACCGCGTACCGCAGGCCAAGACCTCTGGCGACTTGATACGTTGTCCCT

481 LeuProGlyCysSerPheSerThrPhe
 ACCTTCCTGGTTGCTTTCTACCTTC
 TGGAAGGACCAACGAGAAAGAGATGGAAG

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Translation of DNA ag30a

FIG. 12-1

#MetSerValValGlnProProGlyProProLeu

#MetAlaLeuValOP

1 CGCAGAAAGCGTCTAGCCATGGCGTTAGTAGTGTGAGTCAGCCTCCAGGACCCCCCCC
 GCGTCTTCGCAGATCGGTACCGCAATCATACTCACAGCACGTCGGAGGTCTGGGGGGGG
 ProGlyGluProAM

61 TCCCCGGAGAGCCATAGGGTCTGCGAACCGGTGAGTACACCGGAATTGCCAGGACGAC
 AGGGCCCTCTCGGTATCACCAGACGCCCTGGCCACTCATGTGGCTTAACGGTCTGCTG

#MetProGlyAspLeuGlyValProProGlnAsp

121 CGGGTCTTCTGGATCAACCCGCTCAATGCCCTGGAGATTGGCGTCCCCCGCAAGA
 GCCCAGGAAAGAACCTAGTTGGCGAGTTACGGACCTCTAAACCCGACGGGGCGTTCT

OP AM GlyAlaCys

CysAM *

181 CTGCTAGCCGAGTAGTGGTGGTGGCGAAAGGCCTTGTGGTACTGCCGTAGGGTGCTT
 GACGATCGGCTCATCACAAACCCAGCGCTTCCGGAACACCATGACGGACTATCCCACGAA

GluCysProGlyArgSerArgArgProCysThrMetSerThrAsnProLysProGlnLys

241 GCGAGTCCCCGGAGGTCTCGTAGACCGTGCACCATGAGCACGAATCCTAAACCTCAA
 CGCTCACGGGCCCTCCAGAGCATCTGGCACGTGGTACTCGTGTAGGATTGGAGTT
 LysAsnLysArgAsnThrAsnArgArgProGlnAspValLysPheProGlyGlyGln

301 AAAAAAACAAACGTAAACACCAACCGTCGCCACAGGACGTCAAGTTCCGGGTGGCGGTC
 TTTTTTGTGTTGCATTGTGGTGGCAGCGGGTGTGCAGTTCAAGGGCCCACCGCCAG
 IleValGlyGlyValTyrLeuLeuProArgArgGlyProArgLeuGlyValArgAlaThr

361 AGATCGTTGGTGGAGTTACTTGTGCGCGCAGGGGCCCTAGATTGGGTGTGCGCGCGA
 TCTAGCAACCACCTCAAATGAACAACGGCGCGTCCCAGGATCTAACCCACACGCGCGCT
 ArgLysThrSerGluArgSerGlnProArgGlyArgArgGlnProIleProLysAlaArg

421 CGAGAAAGACTTCCGAGCGGTGCAACCTCGAGGTAGACGTCAGCCTATCCCCAAGGCTC
 GCTCTTCTGAAGGCTGCCAGCGTTGGAGCTCCATCTGAGTCGGATAGGGGTTCCGAG
 ArgProGluGlyArgThrTrpAlaGlnProGlyTyrProTrpProLeuTyrGlyAsnGlu

overlap with CA290a

481 GTCGGCCCGAGGGCAGGACCTGGGCTCAGGCCGGTACCCCTGGCCCTCTATGGCAATG
 CAGCCGGGCTCCGTCCGAGTCGGCCATGGGAACCGGGAGATACCGTTAC
 GlyCysGlyTrpAlaGlyTrpLeuLeuSerProArgGlySerArgProSerTrpGlyPro

541 AGGGCTGCGGGTGGCGGGATGGCTCCTGTCTCCCGTGGCTCTCGGCCTAGCTGGGGCC
 TCCCAGCCCACCCGCCCTACCGAGGACAGAGGGCACCGAGAGCCGGATCGACCCCGG
 ThrAspProArgArgSerArgAsnLeuGlyLysValIleAspThrLeuThrCysGly

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601 CCACAGACCCCCGGCGTAGGTCGGCAATTGGGTAAGGTATCGATACCCTACGTGCG
GGTGTCTGGGGGCCGCATCCAGCGCGTTAAACCCATTCCAGTAGCTATGGGAATGCACGC

Phe

661 GCTTC
CGAAG

* = Start of long HCV ORF
| = Putative first amino acid of large HCV polyprotein
= Putative small encoded peptides (that may play a
translational regulatory role)

FIG. 12-2

FIG. 13

Translation of DNA CA205a

1 ValLeuGlyArgGluArgProCysGlyThrAlaOP AM GlyAlaCysGluCysProGly
 GTCTGGGTCGCGAAAGGCCTTGTGGTACTGCCTGATAGGGTGCCTGGAGTGCCTGGG
 CAGAACCCAGCGCTTCCGAACACCATGACGGACTATCCCACGAACGCTCACGGGCC

61 ArgSerArgArgProCysThrMetSerThrAsnProLysProGlnArgLysThrLysArg
 AGGTCTCGTAGACCGTGCACCATGAGCACGAATCCTAAACCTCAAAGAAAAACAAACGT
 TCCAGAGCATCTGGCACGTGGTACTCGTGCCTAGGATTGGAGTTCTTTGGTTGCA

121 AsnThrAsnArgArgProGlnAspValLysPheProGlyGlyGlnIleValGlyGly
 AACACCAACCGTGCACAGGGACGTCAAGTTCCGGGTGGCGGTCAAGATCGTTGGTGA
 TTGTGGTTGGCAGCGGGTGTCCCTGCAGTTCAAGGGCCCACCGCCAGTCTAGCAACCACCT

181 ValTyrLeuLeuProArgArgGlyProArgLeuGlyValArgAlaThrArgLysThrSer
 GTTTACTTGTGCGCGCAGGGGCCCTAGATTGGGTGTGCGCGCAGCAGAAAGACTTCC
 CAAATGAACAACGGCGCGTCCCCGGGATCTAACCCACACGCGCGTGCCTTCTGAAGG

241 overlap with CA290a
 GluArgSerGlnProArgGlyArgArgGlnProIleProLysAlaArgArgProGluGly
 GAGCGGTGCAACCTCGAGGTAGACGTCAGCCTATCCCCAAGGCTCGTGGCCCGAGGGC
 CTCGCCAGCGTTGGAGCTCCATCTGCAGTCGGATAGGGTTCCGAGCAGCCGGCTCCG

301 ArgThrTrpAlaGlnProGlyTyrProTrpProLeuTyrGlyAsnGluGlyCys
 AGGACCTGGGCTCAGCCGGTACCCCTGGCCCCCTATGGCAATGAGGGCTGCG
 TCCTGGACCCGAGTCGGCCCAGGGAAACCGGGGAGATACCGTTACTCCGACGC

* = putative initiator methionine codon

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FIG. 14

Translation of DNA 18g

#ProProOP
 #SerThrMetAsnHisSerProValArgAsnTyrCysLeuHisAlaGluSerValAM Pro
 1 #LeuHisHisGluSerLeuProCysGluGluLeuLeuSerSerArgArgLysArgLeuAla
 CTCCACCATGAATCACTCCCTGTGAGGAACACTACTGTCTCACGCAGAAAGCGTCTAGCC
 GAGGTGGTACTTAGTGAGGGGACACTCCTGATGACAGAAGTGCCTTCAGCAGATCGG

#MetSerValValGlnProProGlyProProLeuProGlyGluProAM
 MetAlaLeuValOP
 61 ATGGCGTTAGTATGAGTGTGCGAGCCTCCAGGACCCCCCTCCGGAGAGGCCATAGT
 TACCGCAATCATACTCACAGCACGTCGGAGGTCCCTGGGGGGAGGGCCCTCTCGGTATCA

121 GGTCTGCGAACCGGTGAGTACACCGGAATTGCCAGGACGACCGGGCTTTCTGGATC
 CCAGACGCCCTGGCCACTCATGTGGCTTAACGGCCTGCTGGCCCAGGAAAGAACCTAG
 overlap with ag30a

#MetProGlyAspLeuGlyValProProGlnAspCysAM
 181 AACCCGCTCAATGCCCTGGAGATTGGCGTGCCCCCGCAAGACTGCTAGCCGAGTAGTGT
 TTGGGCGAGTTACGGACCTCTAACCCGCACGGGGCGTTCTGACGATCGGCTCATCACA

OP AM GlyAlaCysGluCysProGlyArgSer
 *
 241 TGGGTGCGAACAGGCCCTGTGGTACTGCCGTAGGGTGCTTGCAGTGCCCCGGAGGT
 ACCCAGCGCTTCCGGAACACCATGACGGACTATCCCACGAACGCTCACGGGGCCCTCCA
 ArgArg

301 CTCGTAGA
 GAGCATCT

* = Start of long HCV ORF

= Putative small encoded peptides (that may
 play a translational regulatory role)

FIG. 15

Translation of DNA 16jh

Overlap with 15e

1 GlyAlaCysTyrSerIleGluProLeuAspLeuProProIleIleGlnArgLeuHisGly
 GGGGCCCTGCTACTCCATAGAACCACTGGATCTACCTCCAATCATTCAAAGACTCCATGGC
 CCCCAGACGATGAGGTATCTGGTGACCTAGATGGAGGTTAGTAAGTTCTGAGGTACCG

61 LeuSerAlaPheSerLeuHisSerTyrSerProGlyGluIleAsnArgValAlaAlaCys
 CTCAGCGCATTTCACTCCACAGTTACTCTCCAGGTGAAATTAAATAGGGTGGCCGCATGC
 GAGTCGCGTAAAGTGAGGTGTCAATGAGAGGTCCACTTAATTATCCCACCGGGCGTACG

Gly*
G

121 LeuArgLysLeuGlyValProProLeuArgAlaTrpArgHisArgAlaArgSerValArg
 CTCAGAAAACCTGGGGTACGCCCTTGGAGCTTGGAGACACCGGGCCGGAGCGTCCGC
 GAGTCTTGTAAACCCATGGCGGGAACGCTCGAACCTCTGGGCCCGGCCTCGCAGGCG

181 AlaArgLeuLeuAlaArgGlyGlyArgAlaAlaIleCysGlyLysTyrLeuPheAsnTrp
 GCTAGGCTTCTGGCCAGAGGAGGCAGGGCTGCCATATGTGGCAAGTACCTCTCAACTGG
 CGATCCGAAGACCGGTCTCCGTCCGACGGTATACACCGTTATGGAGAAGTTGACC

241 AlaValArgThrLysLeuLys
 GCAGTAAGAACAAAGCTAAAC
 CGTCATTCTGTTGAGTTG

* = nucleotide heterogeneity

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COMBINED ORF OF DNAs pil4a THROUGH 15e

FIG. 16-1

(pil4a/CA167b/CA156e/CA84a/CA59a/K9-1/12f/14i/11b/7f/7e/
 8h/33c/40b/37b/35/36/81/32/33b/25c/14c/8f/33f/33g/39c/
 35f/19g/26g & 15e)

1 ArgSerArgAsnLeuGlyLysValIleAspThrLeuThrCysGlyPheAlaAspLeuMet
 AGGTGCGCGCAATTGGGTAAGGTATCGATACCCCTACGTGCGGCTCGCCGACCTCATG
 TCCAGCGCGTTAACCCATTCCAGTAGCTATGGGAATGCACGCCAAGCGGCTGGAGTAC

61 GlyTyrIleProLeuValGlyAlaProLeuGlyGlyAlaAlaArgAlaLeuAlaHisGly
 GGGTACATACCGCTCGTCGGCGCCCTCTGGAGGCGCTGCCAGGGCCCTGGCGCATGGC
 CCCATGTATGGCGAGCAGCCGGGAGAACCTCCGCGACGGTCCCGGGACCGCGTACCG

121 ValArgValLeuGluAspGlyValAsnTyrAlaThrGlyAsnLeuProGlyCysSerPhe
 GTCCGGGTTCTGGAAGACGGCGTGAACATATGCAACAGGGAACCTCCCTGGTTGCTCTTC
 CAGGCCAAGACCTCTGCCGACTTGATACTGTTGTCCTTGAAGGACCAACGAGAAAG

181 SerIlePheLeuLeuAlaLeuLeuSerCysLeuThrValProAlaSerAlaTyrGlnVal
 TCTATCTCCTCTGGCCCTGCTCTTGCTTGACTGTGCCGCTCGCCTACCAAGTG
 AGATAGAAGGAAGACCGGGACGAGAGAACGAACTGACACGGCGAAGCCGGATGGTTCAC

241 ArgAsnSerThrGlyLeuTyrHisValThrAsnAspCysProAsnSerSerIleValTyr
 CGCAACTCCACGGGGCTTACACGTCACCAATGATTGCCCTAACCGAGTATTGTGTAC
 GCGTTGAGGTGCCCGAAATGGTGCAGTGGTTACTAACGGGATTGAGCTCATAACACATG

301 GluAlaAlaAspAlaIleLeuHisThrProGlyCysValProCysValArgGluGlyAsn
 GAGGCGGCCGATGCCATCCTGCACACTCCGGGTGCGTCCCTGCGTTCGTGAGGGCAAC
 CTCCGCCGCTACGGTAGGACGTGTGAGGCCCCACGCAGGGAACGCAAGCACTCCGTTG

361 AlaSerArgCysTrpValAlaMetThrProThrValAlaThrArgAspGlyLysLeuPro
 GCCTCGAGGTGTTGGGTGGCGATGACCCCTACGGTGGCCACAGGGATGGCAAACCTCCCC
 CGGAGCTCCACAACCCACCGCTACTGGGGATGCCACCGGTGGTCCCTACCGTTGAGGGG

421 AlaThrGlnLeuArgArgHisIleAspLeuLeuValGlySerAlaThrLeuCysSerAla
 GCGACGCTTCGACGTACATCGATCTGCTTGCGTGGGAGCGCCACCCCTGTTGGCC
 CGCTGCGTCGAAGCTGCACTGAGTAGCTAGACGAACAGCCCTCGCGTGGAGACAAGCCGG

481 LeuTyrValGlyAspLeuCysGlySerValPheLeuValGlyGlnLeuPheThrPheSer
 CTCTACGTGGGGACCTATGCGGGTCTGCTTCTGCGGCCACTGTTCACCTCTCT
 GAGATGCACCCCTGGATACGCCACAGAACAGAACAGCCGGTTGACAAGTGGAAAGAGA

541 ProArgArgHisTrpThrThrGlnGlyCysAsnCysSerIleTyrProGlyHisIleThr
 CCCAGGCGCCACTGGACGACGCAAGGTTGCAATTGCTCTATCTATCCGGCCATATAACG
 GGGTCCCGGTGACCTGCTGCGTCCACGTTAACGAGATAGATAGGGCCGGTATATTGC

601 GlyHisArgMetAlaTrpAspMetMetAsnTrpSerProThrThrAlaLeuValMet
 GGTACCGCATGGCATGGGATATGATGATGAACGGTCCCCTACGACGGCGTTGGTAATG
 CCAGTGGCGTACCGTACCCCTACTACTACTTGACCAGGGATGCTGCCGCAACCATTAC

661 AlaGlnLeuLeuArgIleProGlnAlaIleLeuAspMetIleAlaGlyAlaHisTrpGly
 GCTCAGCTGCTCCGGATCCACAAGCCATCTGGACATGATCGCTGGTGTCTCACTGGGA
 CGAGTCGACGAGGCGTAGGGTGTGGTAGAACCTGTACTAGCGACCACGAGTGACCCCT

721 ValLeuAlaGlyIleAlaTyrPheSerMetValGlyAsnTrpAlaLysValLeuValVal
 GTCCTGGCGGGCATAGCGTATTCTCCATGGTGGGAACTGGCGAAGGTCTGGTAGTG
 CAGGACCGCCCGTATCGCATAAAAGAGGTACCACCCCTGACCCGCTTCAAGGACCATCAC

781 LeuLeuLeuPheAlaGlyValAspAlaGluThrHisValThrGlyGlySerAlaGlyHis
 CTGCTGCTATTGCGGGCGTCGACGCCAAACCCACGTCACCGGGGGAAAGTGCCGGCAC
 GACGACGATAAACGGCCGAGCTGCCCTTGGGTGCACTGGCCCCCTCACGGCCGGTG

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FIG. 16-2

841 ThrValSerGlyPheValSerLeuLeuAlaProGlyAlaLysGlnAsnValGlnLeuIle
 ACTGTGTCTGGATTTGTTAGCCTCCTCGACCAGGCGCAAGCAGAACGTCCAGCTGATC
 TGACACAGACCTAACAACTCGGAGGAGCGTGGTCCGGTCTGAGCTGAGTCAGTAG

 901 AsnThrAsnGlySerTrpHisLeuAsnSerThrAlaLeuAsnCysAsnAspSerLeuAsn
 AACACCAACGGCAGTTGGCACCTCAATAGCACGCCCTGAAGTCAATGATAGCCTAAC
 TTGTGGTTGCCGTCAACCGTGGAGTTATCGTGCCTGGACTTGACGTTACTATCGGAGTTG

 961 ThrGlyTrpLeuAlaGlyLeuPheTyrHisHisLysPheAsnSerSerGlyCysProGlu
 ACCGGCTGGTTGGCAGGGCTTTCTATCACCACAAGTTCAACTCTCAGGCTGTCTGAG
 TGGCCGACCAACCGTCCCAGAAAGATACTGGTGTCAAGTTGAGAAGTCCGACAGGACTC

 1021 ArgLeuAlaSerCysArgProLeuThrAspPheAspGlnGlyTrpGlyProIleSerTyr
 AGGCTAGCCAGCTGCCGACCCCTTACCGATTTGACCAGGGCTGGGGCCCTATCAGTTAT
 TCCGATCGGTCGACGGCTGGGAATGGCTAAACTGGTCCCGACCCCGGGATAGTCAATA

 1081 AlaAsnGlySerGlyProAspGlnArgProTyrCysTrpHisTyrProProLysProCys
 GCCAACGGAAGCGGCCCGACCAGGCCCTACTGCTGGCACTACCCCCCAAACCTTGC
 CGGTTGCCCTGCCGGGCTGGTCGCGGGGATGACGACCGTGATGGGGGTTTGAACG

 1141 GlyIleValProAlaLysSerValCysGlyProValTyrCysPheThrProSerProVal
 GGTATTGTGCCCGCGAACAGTGTGTGGTCCGGTATATTGCTTCACCTCCAGGCCGTG
 CCATAAACACGGCGCTCTCACACACACCAGGCCATATAACGAAGTGAGGGTCGGGCAC

 1201 ValValGlyThrThrAspArgSerGlyAlaProThrTyrSerTrpGlyGluAsnAspThr
 GTGGTGGGAACGACCGACAGGTGCGGCCACCTACAGCTGGGTGAAAATGATACG
 CACCACCCCTGCTGGCTGTCCAGCCCGCGCGGGTGGATGTCGACCCCACTTTACTATGC

 1261 AspValPheValLeuAsnAsnThrArgProProLeuGlyAsnTrpPheGlyCysThrTrp
 GACGTCTCGTCTTAACAATACCAGGCCACCGCTGGCAATTGGTCCGGTGTACCTGG
 CTGCAGAACAGGAATTGTTATGGTCCGGTGGCGACCCGTTAACCAAGCCAACATGGACC

 1321 MetAsnSerThrGlyPheThrLysValCysGlyAlaProProCysValIleGlyGlyAla
 ATGAACTCAACTGGATTCAACAAAGTGTGCGGAGCGCCCTGTGTACGGAGGGCG
 TACTTGAGTTGACCTAAGTGGTTTCACACGCCCTCGCGAGGAACACAGTAGCCTCCCCGC

 1381 GlyAsnAsnThrLeuHisCysProThrAspCysPheArgLysHisProAspAlaThrTyr
 GGCAACAAACACCCCTGCACTGCCCACTGATTGCTCCGCAAGCATTGGACGCCACATAC
 CCGTTGTTGTGGACGTGACGGGTGACTAACGAAGCGTTGCTAGGCCCTGCGGTATG

 1441 SerArgCysGlySerGlyProTrpIleThrProArgCysLeuValAspTyrProTyrArg
 TCTCGGTGCGGCTCCGGTCCCTGGATCACACCCAGGTGCCCTGGTCGACTACCCGTATAGG
 AGAGCCACGCCGAGGCCAGGGACCTAGTGTGGTCCACGGACCGCTGATGGCATATCC

 1501 LeuTrpHisTyrProCysThrIleAsnTyrThrIlePheLysIleArgMetTyrValGly
 CTTGGCATTATCCTGTACCATCAACTACACCATATTTAAATCAGGATGTACGTGGGA
 GAAACCGTAATAGAACATGGTAGTTGATGTGGTATAAATTAGTCCTACATGCACCCCT

 1561 GlyValGluHisArgLeuGluAlaAlaCysAsnTrpThrArgGlyGluArgCysAspLeu
 GGGGTGAAACACAGGCTGGAGCTGCCACTGACGCCACTACACAGTGGCAGTC
 CCCCAGCTTGTGTCGACCTCGACGGACGTGACCTGCGCCCCGTTGCAACGCTAGAC

 1621 GluAspArgAspArgSerGluLeuSerProLeuLeuLeuThrThrGlnTrpGlnVal
 GAAGACAGGGACAGGTCCGAGCTCAGCCCCTACTGCTGACCAACTACACAGTGGCAGGTC
 CTTCTGTCCTGTCCAGGCTCGAGTCGGCAATGACGACTGGTATGTGTCACCGTCCAG

 1681 LeuProCysSerPheThrThrLeuProAlaLeuSerThrGlyLeuIleHisLeuHisGln
 CTCCCGTGTCTCACAACCCCTACCAGCCTGTCACCGGCCCTCATCCACCTCCACCAG
 GAGGGCACAAGGAAGTGTGGATGGTCGGAACAGGTGGCCGGAGTAGGTGGAGGTGGTC

 1741 AsnIleValAspValGlnTyrLeuTyrGlyValGlySerSerIleAlaSerTrpAlaIle
 AACATTGTGGACGTGCAGTACTTGTACGGGGTGGGGTCAAGCATCGCCTGGCATT
 TTGTAAACACCTGCACTGATGAACATGCCCAACCCAGTTCGTAGCGCAGGACCCGGTAA

 1801 LysTrpGluTyrValValLeuLeuPheLeuLeuAlaAspAlaArgValCysSerCys
 AAGTGGGAGTACGTGTTCTCTGTTCTGCTGAGACGCGCGTCTGCTCTG

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FIG. 16-3

TTCACCCCTCATGCAGCAAGAGGACAAGGAAGACGAACGTCCTGCGCGCAGACGAGGACG
 1861 LeuTrpMetMetLeuLeuIleSerGlnAlaGluAlaAlaLeuGluAsnLeuValIleLeu
 TTGTGGATGATGCTACTCATATCCCAAGCGGAGGCGCTTGGAGAACCTCGTAATACTT
 AACACCTACTACGATGAGTATAGGGTCTGCCTCCGCCAACCTCTGGAGCATTATGAA
 1921 AsnAlaAlaSerLeuAlaGlyThrHisGlyLeuValSerPheLeuValPhePheCysPhe
 AATGCAGCATCCCTGGCCGGACGCACGGCTTGTATCTCTCGTGTCTGCTTT
 TTACGTCGTAGGGACCGGCCCTGCGTGCCAGAACATAGGAAGGAGCACAAAGAACGAAA
 1981 AlaTrpTyrLeuLysGlyLysTrpValProGlyAlaValTyrThrPheTyrGlyMetTrp
 GCATGGTATTTGAAAGGGTAAGTGGGTGCCCGAGCGGTCTACACCTCTACGGGATGTGG
 CGTACCATAAACTCCCATCACCACGGGCCTGCCAGATGTGGAAGATGCCCTACACC
 2041 ProLeuLeuLeuLeuLeuAlaLeuProGlnArgAlaTyrAlaLeuAspThrGluVal
 CCTCTCCTCCTGCTCTGTTGGCGTTGCCCCAGCGGGCGTACCGCCTGGACACGGAGGTG
 GGAGAGGAGGACGAGGACAACGCCAACGGGTGCCATGCCGACTGAGACAGTGGTATA
 2101 AlaAlaSerCysGlyGlyValValLeuValGlyLeuMetAlaLeuThrLeuSerProTyr
 GCCGCGTCGTGTGGCGGTGTTCTCGTGGGTGATGGCGCTGACTCTGTCACCATAT
 CGGCGCAGCACACGCCAACAAAGAGCAGCCAACCGCAGTGGCTGCCGACTGAGACAGTGGTATA
 2161 TyrLysArgTyrIleSerTrpCysLeuTrpTrpLeuGlnTyrPheLeuThrArgValGlu
 TACAAGCGCTATATCAGCTGGTGTGGTGGCTTCAGTATTTCTGACCAGAGTGGAA
 ATGTTCGCGATATACTGCGACACCGAACACCACCGAAGTCATAAAAGACTGGTCTCACCTT
 2221 AlaGlnLeuHisValTrpIleProProLeuAsnValArgGlyGlyArgAspAlaValIle
 GCGCAACTGCACGTGTGGATTCCCCCTCAACGTCGGAGGGGGCGCGACGCCGTCACTC
 CGCGTTGACGTGACACCTAACGGGGAGTTGCAGGCTCCCCCGCGCTGCCAGTAG
 2281 LeuLeuMetCysAlaValHisProThrLeuValPheAspIleThrLysLeuLeuLeuAla
 TTACTCATGTGTGCTGTACACCCGACTCTGGTATTGACATACCAAAATTGCTGCTGGCC
 AATGAGTACACACGACATGTGGCTGAGACCATAACTGTAGTGGTTAACGACGACCGG
 2341 ValPheGlyProLeuTrpIleLeuGlnAlaSerLeuLeuLysValProTyrPheValArg
 GTCTCGGACCCCTTGGATTCTCAAGCCAGTTGCTAAAGTACCCCTACTTGTCGCG
 CAGAACGCTGGGAAACCTAACGAAGTTCGGTAAACGAATTCTATGGGATGAAACACCGG
 2401 ValGlnGlyLeuLeuArgPheCysAlaLeuAlaArgLysMetIleGlyGlyHisTyrVal
 GTCCAAGGGCTTCCTCGGTTCTGCGCGTTAGCGCGGAAGATGATCGGAGGCCATTACGTG
 CAGGTTCCGGAAGAGGCCAACGCGCAATCGCCCTACTAGCCTCCGGTAATGCAC
 2461 GlnMetValIleIleLysLeuGlyAlaLeuThrGlyThrTyrValTyrAsnHisLeuThr
 CAAATGGTCATCATTAAGTTAGGGCGCTACTGGCACCTATGTTATAACCATCTCACT
 GTTTACCACTAGTAATTCAATCCCCCGCAATGACCGTGGATAACAAATATTGGTAGAGTGA
 2521 ProLeuArgAspTrpAlaHisAsnGlyLeuArgAspLeuAlaValAlaValGluProVal
 CCTCTCAGGACTGGCGCACAACGGCTGCGAGATCTGGCGTGGCTGTAGAGCCAGTC
 GGAGAACCCCTGACCCCGTGTGCCAACGCTCTAGACCGCACCGACATCTCGGTCA
 2581 ValPheSerGlnMetGluThrLysLeuIleThrTrpGlyAlaAspThrAlaAlaCysGly
 GTCTTCTCCCAAATGGAGACCAAGCTCATCACGTGGGGGGCAGATACCGCCGCGTGC
 CAGAACAGGGTTACCTCTGGTTCGAGTAGTGCACCCCCCGTCTATGGCGCGCACGCCA
 2641 AspIleIleAsnGlyLeuProValSerAlaArgArgGlyArgGluIleLeuGlyPro
 GACATCATCAACGGCTTGCCTTTCCGCCCGCAGGGGCCGGAGATACTGCTCGGGCCA
 CTGTAGTAGTTGCCAACGGACAAAGGCCGGTCCCCGGCCCTATGACGAGCCCGT
 2701 AlaAspGlyMetValSerLysGlyTrpArgLeuLeuAlaProIleThrAlaTyrAlaGln
 GCCGATGGAATGGCTCCAAGGGTGGAGGTTGCTGGCGCCCATCACGGCGTACGCCAG
 CGGCTACCTTACCAAGAGGTTCCCCACCTCCAACGACCGCGGGTAGTGCCTGCGCATGCC
 2761 GlnThrArgGlyLeuLeuGlyCysIleIleThrSerLeuThrGlyArgAspLysAsnGln
 CAGACAAAGGGGCCCTCTAGGGTGCATAATCACCAGCCTAACTGGCCGGACAAAAACCAA
 GTCTGTTCCCCGGAGGATCCCACGTATTAGTGGTCGGATTGACCGGCCCTGTTGGTT

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FIG. 16-4

2821 ValGluGlyGluValGlnIleValSerThrAlaAlaGlnThrPheLeuAlaThrCysIle
 GTGGAGGGTGAGGTCCAGATTGTGTCAACTGCTGCCAAACCTCTGGCAACGTGCATC
 CACCTCCCACTCCAGGTCTAACACAGTTGACGACGGGTTGGAAAGGACCGTTGCACGTAG

 2881 AsnGlyValCysTrpThrValTyrHisGlyAlaGlyThrArgThrIleAlaSerProLys
 AATGGGGTGTGCTGGACTGTCTACCACGGGGCCGGAACGAGGACCATCGCGTCACCCAAG
 TTACCCCCACACGACCTGACAGATGGTGCCCCGGCCTGCTCCTGGTAGCGCAGTGGGTTC

 2941 GlyProValIleGlnMetTyrThrAsnValAspGlnAspLeuValGlyTrpProAlaPro
 GGTCTGTCTACCCAGATGTATACCAATGTAGACCAAGACCTTGTGGCTGGCCCGCTCCG
 CCAGGACAGTAGGTCTACATATGGTTACATCTGGTTCTGGAACACCCGACCGGGCGAGGC

 3001 GlnGlySerArgSerLeuThrProCysThrCysGlySerSerAspLeuTyrLeuValThr
 CAAGGTAGCCGCTCATTGACACCCTGCACTTGCGGCTCTCGGACCTTACCTGGTCACG
 GTTCCATCGCGAGTAACGTGGGACGTGAACGCCGAGGAGCCTGGAAATGGACCAAGTGC

 3061 ArgHisAlaAspValIleProValArgArgGlyAspSerArgGlySerLeuLeuSer
 AGGCACGCCGATGTCATTCCCGTGCGCCGGGGTGATAGCAGGGCAGCCTGCTGTGCG
 TCCGTGCGGCTACAGTAAGGGCACGCCGCCCCACTATCGTCCCCGTCGGACGACAGC

 3121 ProArgProIleSerTyrLeuLysGlySerSerGlyGlyProLeuLeuCysProAlaGly
 CCCCCGCCCCATTCTCTACTGTGAAAGGCTCCTCGGGGGTCCGCTGTGCCCCGCGGGG
 GGGGCGGGTAAAGGATGAACTTCCGAGGAGCCCCCAGGCGACAACACGGGGCGCCCC

 3181 HisAlaValGlyIlePheArgAlaAlaValCysThrArgGlyValAlaLysAlaValAsp
 CACGCCGTGGGCATATTTAGGGCCGCGGTGTGCAACCGTGGAGTGGCTAAGGCGGTGGAC
 GTGCGCACCGTATAAAATCCCGGCCACACGTGGCACCTCACGATTCCGCCACCTG

 3241 PheIleProValGluAsnLeuGluThrThrMetArgSerProValPheThrAspAsnSer
 TTTATCCCTGTGAGAACCTAGAGACAACCAGGTCCTCGGGCTACCGTGGCTACGGATAACTCC
 AAATAGGGACACCTCTGGATCTGTGGTACTCCAGGGGCCACAAGTGCCTATTGAGG

 3301 SerProProValValProGlnSerPheGlnValAlaHisLeuHisAlaProThrGlySer
 TCTCCACCACTAGTGCCTCAGAGCTTCAGGTGGCTCACCTCCATGCTCCACAGGCAGC
 AGAGGTGGTCATCACGGGTCTCGAAGGTCCACCGAGTGGAGGTACGAGGGTGTCCGTC

 3361 GlyLysSerThrLysValProAlaAlaTyrAlaAlaGlnGlyTyrLysValLeuValLeu
 GGCAAAAGCACCAAGGTCCCGCTGCATATGCAGCTCAGGGCTATAAGGTGCTAGTACTC
 CCGTTTCTGTGGTCCAGGGCCGACGTACGTCAGTCCCACATTCCACGATCATGAG

 3421 AsnProSerValAlaAlaThrLeuGlyPheGlyAlaTyrMetSerLysAlaHisGlyIle
 AACCCCTCTGTGCTGCAACACTGGCTTGGTGTACATGTCCAAGGCTCATGGGATC
 TTGGGGAGACAACGACGTTGTGACCCGAAACCACGAATGTACAGGTTCCGAGTACCCCTAG

 3481 AspProAsnIleArgThrGlyValArgThrIleThrThrGlySerProIleThrTyrSer
 GATCCTAACATCAGGACCGGGGTGAGAACAAATTACCACTGGCAGCCCCATACGTACTCC
 CTAGGATTGTAGTCTGGCCCCACTCTGTTAATGGTGACCGTCGGGTAGTGCATGAGG

 3541 ThrTyrGlyLysPheLeuAlaAspGlyGlyCysSerGlyGlyAlaTyrAspIleIleIle
 ACCTACGGCAAGTTCTTGCCGACGGGGGTGCTCGGGGGCGTTATGACATAATAATT
 TGGATGCCGTTCAAGGAACGGCTGCCGCCACGAGCCCCCGCGAATACTGTATTATTAA

 3601 CysAspGluCysHisSerThrAspAlaThrSerIleLeuGlyIleGlyThrValLeuAsp
 TGTGACGAGTGCCACTCCACGGATGCCACATCCATCTGGCATCGGCACTGTCTTGAC
 ACACTGCTCACGGTGAGGTGCCTACGGTGTAGGTAGAACCCGTAGCCGTGACAGGAAC

 3661 GlnAlaGluThrAlaGlyAlaArgLeuValValLeuAlaThrAlaThrProProGlySer
 CAAGCAGAGACTGCCGGGGCGAGACTGGTTGTGCTCGCCACCGCCACCCCTCCGGGCTCC
 GTTCGTTCTGACGCCCGCTCTGACCAACACGAGCGGTGGCGGTGGGGAGGCCCCGAGG

 3721 ValThrValProHisProAsnIleGluGluValAlaLeuSerThrThrGlyGluIlePro
 GTCACTGTGCCCATCCCAACATCGAGGAGGTGCTCTGTCCACCACCGGAGAGATCCCT
 CAGTGACACGGGGTAGGGTTGTAGCTCCTCAACGAGACAGGTGGTGGCCTCTAGGGA

 3781 PheTyrGlyLysAlaIleProLeuGluValIleLysGlyGlyArgHisLeuIlePheCys
 TTTTACGGCAAGGCTATCCCCCTCGAAGTAATCAAGGGGGAGACATCTCATCTCTGT

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FIG. 16-5

AAAATGCCGTTCCGATAGGGGGAGCTCATTAGTCCCCCCTCTGTAGAGTAGAAGACA

3841 HisSerLysLysLysCysAspGluLeuAlaAlaLysLeuValAlaLeuGlyIleAsnAla
CATTCAAAGAAGAAGTGCAGACACTGCCGAAAGCTGGTCGCATTGGGCATCAATGCC
GTAAGTTCTCTTCACGCTGCTTGAGCGCGTTCGACCACGCTAACCGTAGTTACGG

3901 ValAlaTyrTyrArgGlyLeuAspValSerValIleProThrSerGlyAspValValVal
GTGGCTACTACCGCGGTCTTGACGTGTCGTACATCCGACCAGCGCGATGTTGTCGT
CACCGGATGATGGCGCCAGAACACTGCACAGGAGTAGGGCTGGTCGCCGTACAACAGCAG

3961 ValAlaThrAspAlaLeuMetThrGlyTyrThrGlyAspPheAspSerValIleAspCys
GTGGCAACCGATGCCCTCATGACCGGTATACCGCGACTTCGACTCGGTAGACTGC
CACCGTTGGCTACGGGAGTACTGGCCATATGGCCGCTGAAGCTGAGCCACTATCTGACG

4021 AsnThrCysValThrGlnThrValAspPheSerLeuAspProThrPheThrIleGluThr
AATACGTGTGTACCCAGACAGTCGATTCAGCCTTGACCCATACCTCACCATGAGACA
TTATGCACACAGTGGGTCTGTCACTAAAGTCGGAATGGGATGGAAGTGGTAACCTGT

4081 IleThrLeuProGlnAspAlaValSerArgThrGlnArgArgGlyArgThrGlyArgGly
ATCACGCTCCCCCAGGATGCTGTCTCCGACTCACGTCGGGCAGGACTGGCAGGGGG
TAGTGCAGGGGGTCTACGACAGAGGGCGTGAGTTGCAGCCCCGTCCTGACCGTCCCC

4141 LysProGlyIleTyrArgPheValAlaProGlyGluArgProSerGlyMetPheAspSer
AAGCCAGGCATCTACAGATTGTGGCACCGGGGAGCGCCCTCCGGCATGTTGACTCG
TTCGGTCCGTAGATGTCTAACACCGTGGCCCCCTCGCGGGAGGCCGTACAAGCTGAGC

4201 SerValLeuCysGluCysTyrAspAlaGlyCysAlaTrpTyrGluLeuThrProAlaGlu
TCCGTCTCTGTGAGTGTCTATGACGCAAGCTGTGTTGGTATGAGCTCACGCCGCCAG
AGGCAGGAGACACTCACGATACTGCGTCCGACACGAAACCATACTCGAGTGCAGGGCGCTC

4261 ThrThrValArgLeuArgAlaTyrMetAsnThrProGlyLeuProValCysGlnAspHis
ACTACAGTTAGGCTACGAGCGTACATGAACACCCGGGGCTCCGTGTGCCAGGACCAT
TGATGTCAATCCGATGCTCGATGTACTTGTGGGGCCCCGAAGGGCACACGGTCTGGTA

4321 LeuGluPheTrpGluGlyValPheThrGlyLeuThrHisIleAspAlaHisPheLeuSer
CTTGAATTTGGGAGGGCGTCTTACAGGCCTCACTCATATAGATGCCCACTTCTATCC
GAACCTAAAACCTCCCGCAGAAATGTCGGAGTGAGTATATCTACGGGTGAAAGATAGG

4381 GlnThrLysGlnSerGlyGluAsnLeuProTyrLeuValAlaTyrGlnAlaThrValCys
CAGACAAAGCAGAGTGGGGAGAACCTCCTTACCTGGTAGCGTACCAAGCCACCGTGTGC
GTCTGTTCTCGTCACCCCTTGGAAAGGAATGGACCATCGCATGGTTCGGTGGCACACG

4441 AlaArgAlaGlnAlaProProSerTrpAspGlnMetTrpLysCysLeuIleArgLeu
GCTAGGGCTCAAGCCCTCCCCCATCGTGGGACCAGATGTGGAAAGTGTGATTGATTCGCC
CGATCCCGAGTTGGGGAGGGGTAGCACCCCTGGTCTACACCTTCACAAACTAACGGGAG

4501 LysProThrLeuHisGlyProThrProLeuLeuTyrArgLeuGlyAlaValGlnAsnGlu
AAGCCCACCCCTCCATGGGCCAACACCCCTGCTATACAGACTGGCGCTGTTCAGAAATGAA
TTCGGGTGGGAGGTACCCGGTTGTGGGACGATATGTCTGACCCGCGACAAGTCTTACTT

4561 IleThrLeuThrHisProValThrLysTyrIleMetThrCysMetSerAlaAspLeuGlu
ATCACCCCTGACGCACCCAGTCACCAAATACATCATGACATGCTGCGCCGACCTGGAG
TAGTGGGACTGCGTGGGTAGTGGTTATGTAGTACTGTACGTACAGCCGGCTGGACCTC

4621 ValValThrSerThrTrpValLeuValGlyGlyValLeuAlaAlaLeuAlaAlaTyrCys
GTCGTACAGCAGCACCTGGGTGCTCGTGGCGCGTCTGGCTGGCTTGGCCGCGTATTGC
CAGCAGTGCCTGGACCCACGAGAACCGCCGCAGGACCGACGAAACCGGCGCATAACG

4681 LeuSerThrGlyCysValValIleValGlyArgValLeuSerGlyLysProAlaIle
CTGTCAACAGGCTCGTGGTCATAGTGGGCAGGGTCGTCTGTCGGGAAGCCGGCAATC
GACAGTTGTCGACGCACCAGTATCACCCGCTCCACGAGAACAGGCCCTCGGCCGTAG

4741 IleProAspArgGluValLeuTyrArgGluPheAspGluMetGluGluCysSerGlnHis
ATACCTGACAGGGAAAGTCTACCGAGAGTTCGATGAGATGGAAGAGTGCTCTCAGCAC
TATGGACTGTCCTCAGGAGATGGCTCTCAAGCTACTCACCTCTCACGAGAGTCGTG

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FIG. 16-6

4801 LeuProTyrIleGluGlnGlyMetMetLeuAlaGluGlnPheLysGlnLysAlaLeuGly
 TTACCGTACATCGAGCAAGGGATGATGCTCGCCGAGCAGTCAGTCAGCAAGCAGAAGGCCCTCGGC
 AATGGCATGTAGCTCGTCCCTACTACAGAGCGCTCGTCAAGTCGTCTTCCGGAGCCG

 4861 LeuLeuGlnThrAlaSerArgGlnAlaGluValIleAlaProAlaValGlnThrAsnTrp
 CTCCTGCAGACCGCGTCCCGTCAGGCAGAGGTTATCGCCCTGCTGCCAGACCAACTGG
 GAGGACGTCTGGCGCAGGGCAGTCGTCTCAAATAGCGGGGACGACAGGTCTGGTTGACC

 4921 GlnLysLeuGluThrPheTrpAlaLysHisMetTrpAsnPheIleSerGlyIleGlnTyr
 CAAAAACTCGAGACCTTCTGGCGAAGCATATGTGAACTTCATCAGTGGATACAATAC
 GTTTTGAGCTCTGGAAGACCCGCTCGTATACACCTTGAAGTAGTCACCCATATGTTATG

 4981 LeuAlaGlyLeuSerThrLeuProGlyAsnProAlaIleAlaSerLeuMetAlaPheThr
 TTGGCGGGCTTGTCAACGCTGCCTGTAACCCCGCATTGCTTCATTGATGGCTTTACA
 AACCGCCCGAACAGTTGCGACGGACCATTGGGGCGGTAACTGAAGTAACCGAAAATGT

 5041 AlaAlaValThrSerProLeuThrThrSerGlnThrLeuLeuPheAsnIleLeuGlyGly
 GCTGCTGTACAGCCCCTAAACCAACTAGCCAAACCCCTCTTCACATATTGGGGGGGG
 CGACGACAGTGGTCGGGTGATTGGTATCGGTTGGAGGAGAAGTTGTATAACCCCCCCC

 5101 TrpValAlaAlaGlnLeuAlaAlaProGlyAlaAlaThrAlaPheValGlyAlaGlyLeu
 TGGGTGGCTGCCAGCTGCCGCCGGCTGCCACTGCTCTTGTGGCGCTGGCTTA
 ACCCACCGACGGGTCGAGCGGGCGGGCCACGGCGATGACGGAAACACCCGCGACCGAAT

 5161 AlaGlyAlaAlaIleGlySerValGlyLeuGlyLysValLeuIleAspIleLeuAlaGly
 GCTGGCGCCGCCATCGGCAGTGGACTGGGAAGGTCTCATAGACATCCTGCAGGG
 CGACCGCGCGGTAGCCGTACAACCTGACCCCTCCAGGAGTATCTGTAGGAACGTCCC

 5221 TyrGlyAlaGlyValAlaGlyAlaLeuValAlaPheLysIleMetSerGlyGluValPro
 TATGGCGCGGGCTGGCGGGAGCTCTTGTGGCATTCAAGATCATGAGCGGTGAGGTCCCC
 ATACCGCGCCCGCACGCCCTCGAGAACACCGTAAGTTCTAGTACTCGCCACTCCAGGGG

 5281 SerThrGluAspLeuValAsnLeuLeuProAlaIleLeuSerProGlyAlaLeuValVal
 TCCACGGAGGACCTGGCAATCTACTGCCGCCATCCTCTGCCCGAGCCCTGTAGTC
 AGGTGCCTCTGGACCAGTTAGATGACGGCGGTAGGAGAGCGGGCCTCGGGAGCATCAG

 5341 GlyValValCysAlaAlaIleLeuArgArgHisValGlyProGlyGluGlyAlaValGln
 GGCCTGGCTGTGCAGCAACTGCGCCGGCACGGTGGCCCGGGCAGGGGGCAGTGCAG
 CCGCACAGACAGTCGTATGACCGGGCGTGCACCGCCGCTCCCCCGTCACGTC

 5401 TrpMetAsnArgLeuIleAlaPheAlaSerArgGlyAsnHisValSerProThrHisTyr
 TGGATGAACCGGCTGATAGCCTCGCCCTCCGGGGAACCATGTTCCCCCACGCACTAC
 ACCTACTTGGCCGACTATCGGAAGCGGAGGGCCCCCTGGTACAAAGGGGTGCGTGATG

 5461 ValProGluSerAspAlaAlaArgValThrAlaIleLeuSerSerLeuThrValThr
 GTGCCGGAGAGCGATGCACTGCCCGTCACTGCCACTCAGCAGCCTCACTGTAACC
 CACGGCCTCTCGCTACGTCGACGGCGCAGTACGGTATGAGTCGTGGAGTGACATTGG

 5521 GlnLeuLeuArgArgLeuHisGlnTrpIleSerSerGluCysThrThrProCysSerGly
 CAGCTCCTGAGGCGACTGCCACCACTGGATAAGCTGGAGTGTACCACTCCATGCTCCGGT
 GTCGAGGACTCCGCTGACGTGGTCACCTATTGAGCCTCACATGGTGAGGTACGAGGCCA

 5581 SerTrpLeuArgAspIleTrpAspTrpIleCysGluValLeuSerAspPheLysThrTrp
 TCCTGGCTAAGGGACATCTGGGACTGGATATGCGAGGTGTGAGCAGCTTAAGACCTGG
 AGGACCGATTCCCTGTAGACCCCTGACCTATAACGCTCCACAACGCTGAAATTCTGGACC

 5641 LeuLysAlaLysLeuMetProGlnLeuProGlyIleProPheValSerCysGlnArgGly
 CTAAAAGCTAACGCTCATGCCACAGCTGCCCTGGATCCCCTTGTGTCCTGCCAGCGCGGG
 GATTTTCGATTGAGTACGGTGTGACGGACCCTAGGGGAAACACAGGACGGTCGCGCCC

 5701 TyrLysGlyValTrpArgValAspGlyIleMetHisThrArgCysHisCysGlyAlaGlu
 TATAAGGGGGCTGGCGAGTGGACGGCATCATGCAACTCGCTGCCACTGTGGAGCTGAG
 ATATTCCCCCAGACCGCTCACCTGCCGTAGTACGTGTGAGCGACGGTGACACCTCGACTC

 5761 IleThrGlyHisValLysAsnGlyThrMetArgIleValGlyProArgThrCysArgAsn
 ATCACTGGACATGTCAAAACGGGACGATGAGGATCGTCGGCTCTAGGACCTGCAGGAAC

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FIG. 16-7

TAG TAGCTGTACAGTTTGCCCTGCTACTCCTAGCAGCCAGGATCCTGGACGTCTTG
 5821 MetTrpSerGlyThrPheProIleAsnAlaTyrThrThrGlyProCysThrProLeuPro
 ATGGAGTGGGACCTTCCCCATTATGCCCTACACCACGGGCCCCGTACCCCCCTTCCT
 TACACCTCACCTGGAGGGTAATTACGGATGTGGTCCCCGGGACATGGGGGAAGGA
 5881 AlaProAsnTyrThrPheAlaLeuTrpArgValSerAlaGluGluTyrValGluIleArg
 GCGCCGAACTACACGTTCGCGCTATGGAGGGTGTCTGCAGAGGAATATGTGGAGATAAGG
 CGCGGCTTGATGTGCAAGCGGATACCTCCCACAGACGTCTCCTTATACACCTCTATTCC
 5941 GlnValGlyAspPheHisTyrValThrGlyMetThrThrAspAsnLeuLysCysProCys
 CAGGTGGGGACTTCCACTACGTGACGGGTATGACTACTGACAATCTAAATGCCGTGC
 GTCCACCCCTGAAGGTGATGCAGTGCCTACTGATGACTGTTAGAGTTACGGGCACG
 6001 GlnValProSerProGluPhePheThrGluLeuAspGlyValArgLeuHisArgPheAla
 CAGGTCCCCTGCCGAATTTCACAGAATTGGACGGGTGCGCCTACATAGGTTTGCG
 GTCCAGGGTAGCGGGCTAAAAAGTGTCTTAACCTGCCACCGGGATGTATCCAAACGC
 6061 ProProCysLysProLeuLeuArgGluGluValSerPheArgValGlyLeuHisGluTyr
 CCCCCCTGCAAGCCCTTGCTGCGGGAGGAGGTATCATTAGACTCCACGAATAC
 GGGGGGACGTTGGAAACGACGCCCTCCATAGTAAGTCTCATCCTGAGGTGCTTATG
 6121 ProValGlySerGlnLeuProCysGluProGluProAspValAlaValLeuThrSerMet
 CCGGTAGGGTCGCAATTACCTTGCGAGGCCGAACCGGACGTGGCGTGTGACGTCCATG
 GGCCATCCCAGCGTTAATGGAACGCTCGGGCTTGGCTGCACCGCACACTGCAAGGTAC
 6181 LeuThrAspProSerHisIleThrAlaGluAlaAlaGlyArgArgLeuAlaArgGlySer
 CTCACTGATCCCTCCCATATAACAGCAGAGGCGCCGGCGAAGGTTGGCGAGGGGATCA
 GAGTGAATAGGGAGGGTATATTGTCGCTCCGCCGGCCCTTCCAACCGCTCCCTAGT
 6241 ProProSerValAlaSerSerSerAlaSerGlnLeuSerAlaProSerLeuLysAlaThr
 CCCCCCTCTGTGGCCAGCTCTCGGCTAGCCAGCTATCCGCTCCATCTCAAGGCAACT
 GGGGGGAGACACCGGTCGAGGAGCCGATCGGTGATAGGGAGGTAGAGAGTTCCGTTGA
 6301 CysThrAlaAsnHisAspSerProAspAlaGluLeuIleGluAlaAsnLeuLeuTrpArg
 TGCACCGCTAACCATGACTCCCCTGATGCTGAGCTCATAGAGGCCAACCTCTATGGAGG
 ACGTGGCGATTGGTACTGAGGGGACTACGACTCGAGTATCTCCGGTTGGAGGATACCTCC
 6361 GlnGluMetGlyGlyAsnIleThrArgValGluSerGluAsnLysValValIleLeuAsp
 CAGGAGATGGCGGCAACATCACCAAGGGTTGAGTCAGAAAACAAAGTGGTGAATTCTGGAC
 GTCCTCTACCCGCCGTTGTAGTGGTCCAACTCAGTCTTTGTTCACCAACTAACGACTG
 6421 SerPheAspProLeuValAlaGluGluAspGluArgGluIleSerValProAlaGluIle
 TCCTTCGATCCGCTTGCGGGAGGAGGACGAGCGGGAGATCTCCGTACCCGCAGAAATC
 AGGAAGCTAGGCGAACACCGCCTCCTCGCTCGCCCTCTAGAGGCATGGCGTCTTTAG
 6481 LeuArgLysSerArgArgPheAlaGlnAlaLeuProValTrpAlaArgProAspTyrAsn
 CTGCGGAAGTCTCGGAGATCGCCCAGGCCCTGCCGTTGGCGCGCCGGACTATAAC
 GACGCCCTCAGAGCCTCTAACGGGTCGGGACGGCAAACCCCGCGCCGGCTGATATTG
 6541 ProProLeuValGluThrTrpLysLysProAspTyrGluProProValValHisGlyCys
 CCCCCGCTAGTGGAGACGTTGAAAAAGCCCGACTACGAACCACCTGTGGTCCATGGCTGT
 GGGGGCGATCACCTCTGACCTTTGCGCTGATGCTTGGTGGACACCAGGTACCGACA
 6601 ProLeuProProProLysSerProProValProProProArgLysLysArgThrValVal
 CCGCTCCACCTCCAAAGTCCCCTCCGTGCTCCGCTCGGAAGAAGCGGACGGTGGTC
 GCGAAGGTGGAGGTTCAAGGGAGGACACGGAGGCGGAGCCTCTCGCCTGCCACAG
 6661 LeuThrGluSerThrLeuSerThrAlaLeuAlaGluLeuAlaThrArgSerPheGlySer
 CTCACTGAATCAACCCTATCTACTGCCTGGCCAGCTGCCACCAAGAAGCTTGGCAGC
 GAGTGAATAGTGGATAGATGACGGAACCGGCTCGAGCGGTGGCTTCGAACCGTCG
 6721 SerSerThrSerGlyIleThrGlyAspAsnThrThrSerSerGluProAlaProSer
 TCCTCAACTTCCGGCATTACGGGCGACAATACGACAACATCCTCTGAGCCCCCCCCCTCT
 AGGAGTTGAAGGCCGTAATGCCGCTGTTATGCTGTTAGGAGACTCGGGCGGGGAAGA

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FIG. 16-8

6781 GlyCysProProAspSerAspAlaGluSerTyrSerSerMetProProLeuGluGlyGlu
 GGCTGCCCCCCCCGACTCCGACGCTGAGTCTATTCCCATGCCCGCCCTGGAGGGGAG
 CCGACGGGGGGCTGAGGCTGCACTCAGGATAAGGAGGTACGGGGGGACCTCCCCCTC

 6841 ProGlyAspProAspLeuSerAspGlySerTrpSerThrValSerSerGluAlaAsnAla
 CCTGGGGATCCGGATCTTAGCGACGGTCATGGTCACGGCAGTAGTGAGGCCAACCG
 GGACCCCTAGGCCTAGAATCGCTGCCAGTACCGAGTGTGCCAGTCATCACTCCGGTTGCGC

 6901 GluAspValValCysCysSerMetSerTyrSerTrpThrGlyAlaLeuValThrProCys
 GAGGATGTCGTGTGCTGCTCAATGTCTTACTCTGGACAGGCGCACTCGTACCCCGTGC
 CTCCTACAGCACACGACGAGTTACAGAATGAGAACCTGTCCCGTGAGCAGTGGGCACG

 6961 AlaAlaGluGluGlnLysLeuProIleAsnAlaLeuSerAsnSerLeuLeuArgHisHis
 GCCGCGGAAAGAACAGAAACTGCCCATCAATGCACTAAGCAACTCGTTGCTACGTCACCCAC
 CGGCGCCTCTTGTCTTGACGGTAGTTACGTGATTGAGTACGATGAGCAGATGCACTGGTG

 7021 AsnLeuValTyrSerThrSerArgSerAlaCysGlnArgGlnLysLysValThrPhe
 AATTGGGTGATTCCACCACCTCACGCAGTGCTGCCAAAGGCAGAACGAAAGTCACATTT
 TTAAACCACATAAGGTGGTGGAGTGCACGAACTGGTTCCGTCTTCAGTGTAAA

 7081 AspArgLeuGlnValLeuAspSerHisTyrGlnAspValLeuLysGluValLysAlaAla
 GACAGACTGCAAGTTCTGGACAGCCATTACCAGGACGTAACAGGAGGTTAAAGCAGCG
 CTGTCAGCTCAAGACCTGTCGTAATGGTCTGCATGAGTCCCTCAATTTCGTGCG

 7141 AlaSerLysValLysAlaAsnLeuLeuSerValGluGluAlaCysSerLeuThrProPro
 GCGTAAAAGTGAAGGCTAACTGCTATCCGTAGAGGAAGCTGCCATGCCAGAAAG
 CGCAGTTTCACTTCCGATTGAACGATAGGCATCTCTCGAACGTCGGACTGCGGGGT

 7201 HisSerAlaLysSerLysPheGlyTyrGlyAlaLysAspValArgCysHisAlaArgLys
 CACTCAGCCAATCCAAGTTGTTATGGGGAAAAGACGTCGGCTGCCATGCCAGAAAG
 GTGAGTCGGTTAGGTTCAAACCAATACCCGTTCTGCAGGCAACGGTACGGTCTTC

 7261 AlaValThrHisIleAsnSerValTrpLysAspLeuLeuGluAspAsnValThrProIle
 GCCGTAACCCACATCAACTCCGTGTGGAAAGACCTCTGGAAAGACAATGTAACACCAATA
 CGGCATTGGTGTAGTTGAGGCACACCTTCTGGAAAGACCTCTGTTACATTGGTTAT

 7321 AspThrThrIleMetAlaLysAsnGluValPheCysValGlnProGluLysGlyArg
 GACACTACCATCATGGCTAAGAACGAGGTTTCTGCCTCAGCCTGAGAAGGGGGTCGT
 CTGTGATGGTAGTACCGATTCTGCTCCAAAAGACGCAAGTCGGACTCTCCCCCAGCA

 7381 LysProAlaArgLeuIleValPheProAspLeuGlyValArgValCysGluLysMetAla
 AAGCCAGCTCGTCTCATCGTGTCCCCGATCTGGCGTGCCTGCGAAAAGATGGCT
 TTCGGTCGAGCAGAGTAGCACAAGGGCTAGACCCGCACGCGCACACGCTTTCTACCGA

 7441 LeuTyrAspValValThrLysLeuProLeuAlaValMetGlySerSerTyrGlyPheGln
 TTGTACGACGTGGTTACAAAGCTCCCTTGGCGTGTGGAAAGCTCCTACGGATTCCAA
 AACATGCTGACCAATGTTGAGGGAACCGGCACTACCTTCGAGGATGCCATAAGGTT

 7501 TyrSerProGlyGlnArgValGluPheLeuValGlnAlaTrpLysSerLysLysThrPro
 TACTCACCAAGGACAGCGGGTTGAATTCTCGTGCAGCGTGGAAAGTCCAAGAAAACCCA
 ATGAGTGGTCCTGTCGCCAACCTTAAGGAGCACGTTGCACCTTCAGGTTCTTGGGGT

 7561 MetGlyPheSerTyrAspThrArgCysPheAspSerThrValThrGluSerAspIleArg
 ATGGGGTTCTCGTATGATACCCCTGCTTGACTCCACAGTCAGTGAGAGCGACATCGT
 TACCCCAAGAGCATACTATGGCGACGAAACTGAGGTGTCAGTGAACCTCGCTGTAGGCA

 7621 ThrGluGluAlaIleTyrGlnCysCysAspLeuAspProGlnAlaArgValAlaIleLys
 ACGGAGGAGGCAATCTACCAATGTTGACCTCGACCCCCAAGCCCGCTGCCATCAAG
 TGCCTCCTCCGTTAGATGGTACAAACACTGGAGCTGGGGTTGGCGCACCGGTAGITC

 7681 SerLeuThrGluArgLeuTyrValGlyGlyProLeuThrAsnSerArgGlyGluAsnCys
 TCCCTCACCGAGAGGTTTATGTTGGGGCCCTTACCAATTCAAGGGGGGAGAACTGC
 AGGGAGTGGCTCTCCGAAATAACACCCCCGGGAGAATGGTTAACGTTCCCCCTTTGACG

 7741 GlyTyrArgArgCysArgAlaSerGlyValLeuThrThrSerCysGlyAsnThrLeuThr
 GGCTATCGCAGGTGCCGCGCAGCGGGTACTGACAACTAGCTGGTAACACCCTCACT

FIG. 16-9

CCGATAGCGTCCACGGCGCGCTGCCGCATGACTGTTGATCGACACCATTGTGGGAGTGA
 7801 CysTyrIleLysAlaArgAlaAlaCysArgAlaAlaGlyLeuGlnAspCysThrMetLeu
 TGCTACATCAAGGCCGGCAGCCTGTCGAGCCGAGGGCTCCAGGACTGCACCATGCTC
 ACGATGTAGTTCCGGGCCCCGTCGGACAGCTCGCGTCCCGAGGTCTGACGTGGTACGAG
 7861 ValCysGlyAspAspLeuValValIleCysGluSerAlaGlyValGlnGluAspAlaAla
 GTGTGTGGCGACGACTTAGTCGTTATCTGTGAAAGCGCGGGGGTCCAGGAGGACGCGCG
 CACACACCGCTGCTGAATCAGCAATAGACACTTCGCGCCCCCAGGTCTCCTGCGCCGC
 7921 SerLeuArgAlaPheThrGluAlaMetThrArgTyrSerAlaProProGlyAspProPro
 AGCCTGAGAGCCTTCACGGAGGCTATGACCAGGTACTCCGCCCTGGGGACCCCCCA
 TCGGACTCTCGGAAGTGCCTCCGATACTGGTCCATGAGGCGGGGGGGACCCCTGGGGGT
 7981 GlnProGluTyrAspLeuGluLeuIleThrSerCysSerSerAsnValSerValAlaHis
 CAACCGAAATACGACTGGAGCTCATAACATCATGCTCCTCAACGTGTCAGTCGCCAC
 GTTGGTCTTATGCTGAACCTCGAGTATTGTAGTACGAGGAGGTTGCACAGTCAGCGGGTG
 8041 AspGlyAlaGlyLysArgValTyrTyrLeuThrArgAspProThrThrProLeuAlaArg
 GACGGCGCTGGAAAGAGGGTCTACTACCTCACCCGTGACCCTACAACCCCCCTCGCGAGA
 CTGCCGCGACCTTCTCCAGATGATGGAGTGGCACTGGGATGTTGGGGGAGCGCTCT
 8101 AlaAlaTrpGluThrAlaArgHisThrProValAsnSerTrpLeuGlyAsnIleIleMet
 GCTGCGTGGGAGACAGCAAGACACACTCCAGTCAATTCTGGCTAGGCAACATAATCATG
 CGACGCACCCCTCTGCGTTCTGTGAGGTCAAGGACCGATCCGTTGATTAGTAC
 8161 PheAlaProThrLeuTrpAlaArgMetIleLeuMetThrHisPhePheSerValLeuIle
 TTTGCCCTCACACTGTGGGCGAGGATGATACTGATGACCCATTCTTAGCGTCCTTATA
 AACGGGGGTGTGACACCCGCTCTACTATGACTACTGGTAAAGAAATCGCAGGAATAT
 8221 AlaArgAspGlnLeuGluGlnAlaLeuAspCysGluIleTyrGlyAlaCysTyrSerIle
 GCCAGGGACCAGCTTGAACACAGGCCCTCGATTGCGAGATCTACGGGGCTGCTACTCCATA
 CGGTCCCTGGTCGAACCTGTCCGGAGCTAACGCTCTAGATGCCCGGACGATGAGGTAT
 8281 GluProLeuAspLeuProProIleIleGlnArgLeu
 GAAACCACTTGATCTACCTCCAATCATTCAAAGACTC
 CTTGGTGAACTAGATGGAGGTTAGTAAGTTCTGAG

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FIG. 17-1

-319 CACTCCACCATGAATCACTCCCTGTGAGGAACACTGTCTTCACGCAGAAAGCGTCTAG
 GTGAGGTGGTACTTAGTGAGGGACACTCCTGATGACAGAAGTGCCTTCAGCAGATC
 -259 CCATGGCGTTAGTATGAGTGTGCGCAGCCTCCAGGACCCCCCTCCGGGAGAGCCATA
 GGTACCGCAATCATACTCACAGCACGTCGGAGGTCTGGGGGGAGGGCCCTCTCGGTAT
 -199 GTGGTCTGCGGAACCGGTGAGTACACCGGAATTGCCAGGACGACCGGGTCTTCTTGG
 CACAGACGCCTGGCCACTCATGTGCCCTAACGGTCTGCTGGCCAGGAAAGAACCT
 -139 TCAACCCGCTCAATGCCTGGAGATTGGCGTCCCCCGCAAGACTGCTAGCCGAGTAGT
 AGTTGGCGAGTTACGGACCTCTAACCCGCACGGGGCGTCTGACGATCGGCTCATCA
 - 79 GTTGGGTGCGAAAGGCTGTGGTACTGCCTGATAGGGTGTGCGAGTGCCCCGGAG
 CAACCCAGCGTTCCGGAACACCATGACGGACTATCCCACGAACGCTCACGGGCCCTC
 - 19 GTCTCGTAGACCGTGCACC
 CAGAGCATCTGGCACGTGG

Arg Thr

1 MetSerThrAsnProLysProGlnLysLysAsnLysArgAsnThrAsnArgArgProGln
 ATGAGCACGAATCCTAAACTCAAAAAAAACAAACGTAACACCAACCGTCGCCACAG
 TACTCGTGTAGGATTGGAGTTTTTTTTGTTGCATTGTGGTTGGCAGCGGGTGTC

61 AspValLysPheProGlyGlyGlyGlnIleValGlyGlyValTyrLeuLeuProArgArg
 GACGTCAAGTTCCCGGGTGGCGGTCAAGATCGTTGGTGGAGTTACTGTTGCCGCGCAGG
 CTGCAGTTCAAGGGCCCACCGCCAGTCTAGCAACCACCTCAAATGAAACAACGGCGGTCC

121 GlyProArgLeuGlyValArgAlaThrArgLysThrSerGluArgSerGlnProArgGly
 GCCCTAGATTGGGTGTGCGCGCAGCAGAGAAAGACTTCCGAGCGGTCGCAACCTCGAGGT
 CGGGATCTAACCCACACGCGCGCTGCTTTCTGAAGGCTCGCCAGCGTTGGAGCTCCA

181 ArgArgGlnProIleProLysAlaArgArgProGluGlyArgThrTrpAlaGlnProGly
 AGACGTCAAGCTATCCCCAAGGCTCGCGCCAGGGCAGGACCTGGGCTCAGCCCGGG
 TCTGCAGTCGGATAGGGGTCCGAGCAGCGGGCTCCGCTGGACCCGAGTCGGGGCCC

241 TyrProTrpProLeuTyrGlyAsnGluGlyCysGlyTrpAlaGlyTrpLeuLeuSerPro
 TACCCCTGGCCCCCTATGGCAATGAGGGCTGCCGGGATGGCTCCTGTCCTCCC
 ATGGGAACCGGGGAGATACCGTTACTCCGACGCCAACCGCCCTACCGAGGACAGAGGG

301 ArgGlySerArgProSerTrpGlyProThrAspProArgArgSerArgAsnLeuGly
 CGTGGCTCTGGCCTAGCTGGGCCCCACAGACCCCGCGTAGGTGCGCAATTGGGT
 GCACCGAGAGCGGATCGACCCGGGTCTGGGGCCGATCCAGCGCGTTAACCCA

361 LysValIleAspThrLeuThrCysGlyPheAlaAspLeuMetGlyTyrIleProLeuVal
 AAGGTCATCGATACCCCTACGTGCGGCTCGCCGACCTCATGGGTACATACCGCTCGTC
 TTCCAGTAGCTATGGGAATGCACGCCAAGCGGCTGGAGTACCCATGTATGGCGAGCAG

421 GlyAlaProLeuGlyGlyAlaAlaArgAlaLeuAlaHisGlyValArgValLeuGluAsp
 GGCGCCCTCTGGAGGCGCTGCCAGGGCCCTGGCGCATGGCTGGGTTCTGGAAAGAC
 CGCGGGGAGAACCTCCCGACGGTCCCAGGACCGCGTACCGCAGGCCAAGACCTCTG

Thr

481 GlyValAsnTyrAlaThrGlyAsnLeuProGlyCysSerPheSerIlePheLeuLeuAla
 GGCCTGAACATGCAACAGGGAACCTCCCTGGTGTCTTCTCTATCTTCTGCGCC
 CCGCACTTGATACTGGTGTCCCTTGGAAAGGACCAACGAGAAAGAGATAGAAGGAAGACCGG

541 LeuLeuSerCysLeuThrValProAlaSerAlaTyrGlnValArgAsnSerThrGlyLeu
 CTGCTCTTGCTTGACTGTGCCGCTCGGCCTACCAAGTGCACACTCCACGGGGCT
 GACGAGAGAACGAACTGACACGGCGAACGCCGATGGTCACCGTGTGGAGGTGCCGAA

601 TyrHisValThrAsnAspCysProAsnSerSerIleValTyrGluAlaAlaAspAlaIle
 TACCACTGTCACCAATGATTGCCCTAACCGAGTATTGTGTACGAGGCGGCCATGCCATC
 ATGGTGCAGTGGTTACTAACGGGATTGAGCTCATACACATGCTCCGCCGGCTACGGTAG

661 LeuHisThrProGlyCysValProCysValArgGluGlyAsnAlaSerArgCysTrpVal
 CTGCACACTCCGGGGTGCCTCCCTGGCTGAGGGCAACGCCCTCGAGGTGTTGGGTG
 GACGTGTGAGGCCAACGCAGGGAACGCAAGCAGCTCCGTTGCGGAGCTCCACAACCCAC

FIG. 17-2

721 AlaMetThrProThrValAlaThrArgAspGlyLysLeuProAlaThrGlnLeuArgArg
 GCGATGACCCCTACGGTGCCACCAGGGATGGCAAACCTCCCAGCAGCTTCGACGT
 CGCTACTGGGGATGCCACCGTGGTCCCTACCGTTGAGGGGCGCTGCGTCGAAGCTGCA

 781 HisIleAspLeuLeuValGlySerAlaThrLeuCysSerAlaLeuTyrValGlyAspLeu
 CACATCGATCTGCTTGTGGGAGGCCACCCTCTGTTGGCCCTCTACGTGGGGGACCTA
 GTGTAGCTAGACGAACAGCCCTCGCGGTGGGAGACAAGCCGGAGATGCACCCCTGGAT

 841 CysGlySerValPheLeuValGlyGlnLeuPheThrPheSerProArgArgHisTrpThr
 TGCGGGTCTGCTTTCTTGTGGCCAACGTTCACCTCTCCAGGCGCCACTGGACG
 ACGCCCAGACAGAAAGAACAGCCGGTTGACAAGTGGAAGAGAGGGTCCGCGGTGACCTGC

 901 ThrGlnGlyCysAsnCysSerIleTyrProGlyHisIleThrGlyHisArgMetAlaTrp
 ACGCAAGGTTGCAATTGCTCTATCTATCCCAGGCAATAACGGGTACCGCATGGCATGG
 TGCCTTCAACGTTAACGAGATAGATAGGGCCGGTATATTGCCCAGTGGCGTACCGTACC

 961 AspMetMetMetAsnTrpSerProThrThrAlaLeuValMetAlaGlnLeuLeuArgIle
 Val
 GATATGATGATGAACTGGTCCCCTACGACGGCGTGGTAATGGCTCAGCTGCTCCGGATC
 CTATACTACTTGACCAGGGATGCTGCCAACCAATTACCGAGTCGACGAGGGCTAG

 1021 ProGlnAlaIleLeuAspMetIleAlaGlyAlaHisTrpGlyValLeuAlaGlyIleAla
 CCACAAGCCATCTTGGACATGATCGCTGGTGCTACTGGGAGTCCTGGCGGGCATAGCG
 GGTGTTGGTAGAACCTGTACTAGCGACCACGAGTGACCCCTCAGGACCGCCGTATCGC

 1081 TyrPheSerMetValGlyAsnTrpAlaLysValLeuValLeuLeuLeuPheAlaGly
 TATTCTCCATGGTGGGAACTGGGCGAAGGTCTGGTAGTGCTGCTGCTATTGCGGGC
 ATAAAGAGGTACCAACCCCTTGACCCGCTTCCAGGACCATCACGACGACGATAAACGGCCG

 1141 ValAspAlaGluThrHisValThrGlyGlySerAlaGlyHisThrValSerGlyPheVal
 GTCGACGCGGAAACCCACGTCACCAGGGGAAGTGCAGGCAACTGTGTCTGGATTGTT
 CAGCTGCGCTTGGTGCACTGGCCCCCTCACGGCCGGTGTGACACAGACCTAAACAA

 1201 SerLeuLeuAlaProGlyAlaLysGlnAsnValGlnLeuIleAsnThrAsnGlySerTrp
 AGCCTCTCGCACCAAGGCGCAAGCAGAACGTCAGCTGATCAACACCAACGGCAGTTGG
 TCGGAGGAGCGTGGTCCCGGGTTCGACTAGTTGTGGTTGCCGTCAACC

 1261 HisLeuAsnSerThrAlaLeuAsnCysAsnAspSerLeuAsnThrGlyTrpLeuAlaGly
 CACCTCAATAGCACGGCCCTGAACTGCAATGATAGCCTCAACACCGGCTGGTGGCAGGG
 GTGGAGTTATCGTGCCGGACTTGACGTTACTATCGGAGTTGTGGCCGACCAACCGTCCC

 1321 LeuPheTyrHisHisLysPheAsnSerSerGlyCysProGluArgLeuAlaSerCysArg
 CTTTCTATCACACAAGTCAACTCTCAGGCTGTCTGAGAGGCTAGCCAGCTGCCGA
 GAAAAGATAGTGGTGTCAAGTTGAGAAAGTCCGACAGGACTCTCCGATCGGTGACGGCT

 1381 ProLeuThrAspPheAspGlnGlyTrpGlyProIleSerTyrAlaAsnGlySerGlyPro
 CCCCTACCGATTTGACCAGGGCTGGGCCCTATCAGTTATGCCAACGGAAGCGGCC
 GGGGAATGGCTAAACTGGCCCGACCCGGGATAGTCATAACGGTTGCCCTCGCCGGGG

 1441 AspGlnArgProTyrCysTrpHisTyrProProLysProCysGlyIleValProAlaLys
 GACCAGCGCCCTACTGCTGGCACTACCCCCCAAAACCTGCGGTATTGTGCCCGCGAAG
 CTGGTCGCGGGGATGACGACCGTGATGGGGGTTTGGAACGCCATAACACGGCGCTTC

 1501 SerValCysGlyProValTyrCysPheThrProSerProValValValGlyThrThrAsp
 AGTGTGTGTGGTCCGGTATATTGCTTCACCCCAGCCCCGTGGTGGGAAACGACCGAC
 TCACACACACCAGGCCATAACGAAGTGAGGGTCGGGGCACCACCCCTGCTGGCTG

 1561 ArgSerGlyAlaProThrTyrSerTrpGlyGluAsnAspThrAspValPheValLeuAsn
 AGGTGGGGCGCGCCGCCACCTACAGCTGGGGTGAAAATGATACGGACGTCTCGTCCTAAC
 TCCAGCCCCGCGCGGGTGGATGTCGACCCACTTTACTATGCCCTGCAGAACAGGAAATTG

 1621 AsnThrArgProProLeuGlyAsnTrpPheGlyCysThrTrpMetAsnSerThrGlyPhe
 AATACCAGGCCACCGCTGGCAATTGGTTGGTGTACCTGGATGAACCTCAACTGGATT
 TTATGGTCGGTGGCGACCGTAAACCAAGCCAACATGGACCTACTTGAGTTGACCTAAC

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FIG. 17-3

1681 ThrLysValCysGlyAlaProProCysValIleGlyGlyAlaGlyAsnAsnThrLeuHis
ACCAAAGTGTGCGGAGCGCCCTCCTGTCATCGGAGGGGGGGCAACAAACACCTGCAC
TGGTTCACACGCCCTCGCGGAGGAACACAGTAGCCTCCCCGCCGTGTTGTGGGACGTG

1741 CysProThrAspCysPheArgLysHisProAspAlaThrTyrSerArgCysGlySerGly
TGCCCCACTGATTGCTTCCGCAAGCATCCGGACGCCACATACTCTCGGTGCGGCTCCGGT
ACGGGGTGAACGAAGGCGTCTCGTAGGCCTGCGGTGAGAGGCCACGCCGAGGCCA

Leu

1801 ProTrpIleThrProArgCysLeuValAspTyrProTyrArgLeuTrpHisTyrProCys
CCCTGGATCACACCCAGGTGCGCTGGTCGACTACCCGTATAGGCTTGGCATTATCCTGT
GGGACCTAGTGTGGTCCACGGACCAGCTGATGGGCATATCCGAAACCGTAATAGGAACA

1861 ThrIleAsnTyrThrIlePheLysIleArgMetTyrValGlyGlyValGluHisArgLeu
ACCATCAACTACACCATATTAAATCAGGATGTACGTGGAGGGGTCGAACACAGGCTG
TGGTAGTTGATGTGGTATAAATTTAGTCCTACATGCACCCCTCCCCAGCTTGTGTCAGC

1921 GluAlaAlaCysAsnTrpThrArgGlyGluArgCysAspLeuGluAspArgAspArgSer
GAAGCTGCCTGCAACTGGACGCGGGCGAACGTTGCGATCTGGAAGACAGGGACAGGTCC
CTTCGACGGACGTTGACCTGCGCCCCGCTTGCACGCTAGACCTCTGTCCTGTCCAGG

1981 GluLeuSerProLeuLeuLeuThrThrGlnTrpGlnValLeuProCysSerPheThr
GAGCTCAGCCCGTTACTGCTGACCACTACACAGTGGCAGGTCCCTCCGTTGCTTCACA
CTCGAGTCGGGCAATGACGACTGGTGTACCGTCCAGGAGGGCACAGGAAGTGT

2041 ThrLeuProAlaLeuSerThrGlyLeuIleHisLeuHisGlnAsnIleValAspValGln
ACCCTACCAGCCTTGTCCACCGGCCTCATCCACCTCCACCAGAACATTGTGGACGTGCG
TGGGATGGTCGGAACAGGTGGCGGAGTAGGTGGAGGTGTTGTAACACCTGCACGTC

2101 TyrLeuTyrGlyValGlySerSerIleAlaSerTrpAlaIleLysTrpGluTyrValVal
TACTTGACGGGGTGGGTCAAGCATCGCGTCTGGCCATTAAAGTGGAGTACGTCGTT
ATGAACATGCCAACCCAGTCGTAGCGCAGGACCCGGTAATTACCTCATGCAGCAA

2161 LeuLeuPheLeuLeuAlaAspAlaArgValCysSerCysLeuTrpMetMetLeuLeu
CTCCTGTTCTCTGCTTGAGACGCGCGTCTGCTCTGTTGAGTGTGCTACTC
GAGGACAAGGAAGACGAACGCTGCGCGCAGACGAGGACGAACACCTACTACGATGAG

2221 IleSerGlnAlaGluAlaAlaLeuGluAsnLeuValIleLeuAsnAlaAlaSerLeuAla
ATATCCAAGCGGAGGCGGCTTGGAGAACCTCGTAATACTTAATGAGCAGCATCCCTGGCC
TATAGGGTTCGCTCCGCCAACCTCTGGAGCATTATGAATTACGTCGTAGGGACCGG

2281 GlyThrHisGlyLeuValSerPheLeuValPhePheCysPheAlaTrpTyrLeuLysGly
GGGACGACCGTCTTGATCTCTCGTCTGCTTGCATGGTATTGAAAGGGT
CCCTGCGTGCAGAACATAGGAAGGAGCACAAAGAACGAAACGTACCAAACTCCCA

2341 LysTrpValProGlyAlaValTyrThrPheTyrGlyMetTrpProLeuLeuLeuLeu
AAAGTGGGTGCCCAGCGGTCTACACCTCTACGGGATGTGGCCTCCTCCTGCTCTG
TTCACCCACGGGCCTCGCCAGATGTGGAAGATGCCCTACACCGGAGAGGAGCAGGAC

2401 LeuAlaLeuProGlnArgAlaTyrAlaIleLeuAspThrGluValAlaAlaSerCysGlyGly
TTGGCGTTGCCCCAGCGGGCTACGCGCTGGACACGGAGGTGGCGCGTGTGGCGGT
AACCGCAACGGGGTGCCTCGCCAGTGCACGACTGTGCGCTCCACCGCGCAGCACACCGCCA

2461 ValValLeuValGlyLeuMetAlaLeuThrLeuSerProTyrTyrLysArgTyrIleSer
GTTGTTCTCGTCGGGTTGATGGCGCTGACTCTGACCATATAACAAGCGCTATATCAGC
CAACAAGAGCAGCCCAACTACCGCGACTGAGACAGTGGTATAATGTCGCGATATAGTCG

Asn

2521 TrpCysLeuTrpTrpLeuGlnTyrPheLeuThrArgValGluAlaGlnLeuHisValTrp
TGGTGCTGTGGCTTCAGTATTTCTGACCAAGAGTGGAAAGCGCAACTGCACGTGTGG
ACCACGAACACCACCGAACGTACATAAAAGACTGGCTCACCTCGCGTTGACGTGCACACC

2581 IleProProLeuAsnValArgGlyGlyArgAspAlaValIleLeuLeuMetCysAlaVal
ATTCCCCCCTCAACGTCCAGGGGGGGCGACGCCGTACCTTACTCATGTGTGCTGTA
TAAGGGGGGGAGTTGCAAGGCTCCCCCGCGTGCAGTAGAATGAGTACACACGACAT

FIG. 17-4

2641 HisProThrLeuValPheAspIleThrLysLeuLeuLeuAlaValPheGlyProLeuTrp
 CACCCGACTCTGGTATTCGACATCACCAAATTGCTGCTGGCCGTCTCGGACCCCTTG
 GTGGGCTGAGACCATAAACTGTAGTGGTTAACGACGACCGGCAGAACCTGGGAAACC

 2701 IleLeuGlnAlaSerLeuLeuLysValProTyrPheValArgValGlnGlyLeuLeuArg
 ATTCTTCAAGCAGTTGCTTAAAGTACCCCTACTTTGTGCGCGTCCAAGGCCTCTCCGG
 TAAGAAGTTCGGTCAAACGAATTTCATGGGATGAAACACGCGCAGGTCCGGAAAGAGGCC

 2761 PheCysAlaLeuAlaArgLysMetIleGlyGlyHisTyrValGlnMetValIleIleLys
 TTCTGCGCGTTAGCGCGGAAGATGATCGGAGGCCATTACGTGCAAATGGTCATCATTAAG
 AAGACGCGCAATCGCGCTCTACTAGCCTCCGTAATGCACGTTACCAAGTAGTAATT

 2821 LeuGlyAlaLeuThrGlyThrTyrValTyrAsnHisLeuThrProLeuArgAspTrpAla
 TTAGGGGCGCTTACTGGCACCTATGTTATAACCATCTCACTCCTCTCGGGACTGGCG
 AATCCCCGCGAATGACCGTGGATACAAATATTGGTAGAGTGAGGAGAACGGCTGACCGC

 2881 HisAsnGlyLeuArgAspLeuAlaValAlaValGluProValValPheSerGlnMetGlu
 CACAACGGCTTGCAGATCTGGCCGTGGCTGTAGAGGCCAGTCGTCTCTCCCAAATGGAG
 GTGTTGCCGAACGCTCTAGACCGCACCGACATCTGGTCAGCAGAACAGGGTTACCTC

 2941 ThrLysLeuIleThrTrpGlyAlaAspThrAlaAlaCysGlyAspIleIleAsnGlyLeu
 ACCAACGCTCATCACGTGGGGGGCAGATACCGCCGCGTGCAGTCATCAACGGCTTG
 TGGTCGAGTAGTGCACCCCCCGTCTATGGCGGCCACGCCACTGTAGTAGTTGCCGAAC

 3001 ProValSerAlaArgArgGlyArgGluIleLeuLeuGlyProAlaAspGlyMetValSer
 CCTGTTTCCGCCCGCAGGGGCCGGAGATACTGCTGGGCCAGCGATGGAATGGCTC
 GGACAAAGGCGGGCGTCCCCGGCCCTATGACGAGCCGGCTGGCTACCTTACCAAGGAG

 3061 LysGlyTrpArgLeuLeuAlaProIleThrAlaTyrAlaGlnGlnThrArgGlyLeuLeu
 AAGGGGTGGAGGTTGCTGGCGCCCATCACGGCGTACGCCAGCAGACAAGGGCCCTCTA
 TTCCCCACCTCCAACGACCGCGGGTAGTGCACGGGTCTGTACCTCCCCGGAGGAT

 3121 GlyCysIleIleThrSerLeuThrGlyArgAspLysAsnGlnValGluGlyGluValGln
 GGGTGCATAATCACCAAGCCTAACTGGCGGGACAAAAACCAAGTGGAGGGTGAGGTCCAG
 CCCACGTATTAGTGGTCGGATTGACCGGCCCTGTTGGTCACCTCCACTCCAGGTC

 3181 IleValSerThrAlaAlaGlnThrPheLeuAlaThrCysIleAsnGlyValCysTrpThr
 ATTGTGTCAACTGCTGCCAACCTCTGGCAACGTGCATCAATGGGTGTGCTGGACT
 TAACACAGTTGACGACGGTTGAAAGGACCGTTGCACGTAGTTACCCCACACGACCTGA

 3241 ValTyrHisGlyAlaGlyThrArgThrIleAlaSerProLysGlyProValIleGlnMet
 GTCTACCACGGGGCGGAACGAGGACCATCGCGTACCCAGGGCTCTGCATCCAGATG
 CAGATGGTGCCCGGCTTGCTCTGGTAGCGCAGTGGTTCCCAGGACAGTAGGTCTAC

 3301 TyrThrAsnValAspGlnAspLeuValGlyTrpProAlaProGlnGlySerArgSerLeu
 TATACCAATGTAGACCAAGACCTTGTGGCTGGCCGCTCCGCAAGGTAGCCGCTATTG
 ATATGGTTACATCTGGTTCTGGAACACCCGACCGGGCGAGGCGTCCATGGCGAGTAAC

 3361 ThrProCysThrCysGlySerSerAspLeuTyrLeuValThrArgHisAlaAspValIle
 ACACCCCTGCACCTGCGGCTCTCGGACCTTACCTGGTCACGAGGCACGCCGATGTCATT
 TGTGGGACGTGAACGCCGAGGGAGCCTGGAAATGGACCAAGTGCCTCGTGCAGCTACAGTAA

 3421 ProValArgArgArgGlyAspSerArgGlySerLeuLeuSerProArgProIleSerTyr
 CCCGTGCGCCGGCGGGGTGATAGCAGGGCAGCCTGCTGTCGCCCGGCCATTCTAC
 GGGCACGCCGCCCCACTATCGTCCCCGTCGGACGACAGCGGGGCCGGTAAAGGATG

 3481 LeuLysGlySerSerGlyGlyProLeuLeuCysProAlaGlyHisAlaValGlyIlePhe
 TTGAAAGGCTCTCGGGGGTCCGCTGTGTCACGGCCGAGGCCATATT
 AACTTCCGAGGAGCCCCCAGGCGACAACACGGGGCGCCCGTGCAGCACCGTATAAA

 3541 ArgAlaAlaValCysThrArgGlyValAlaLysAlaValAspPheIleProValGluAsn
 AGGGCCGCGGTGTGCACCGTGGAGTGGCTAACGGCGGTGGACATTATCCCTGTGGAGAAC
 TCCCAGGCGCCACACGTGGCACCTCACCGATTCCGCCACCTGAAATAGGGACACCTCTTG

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FIG. 17-5

3601 LeuGluThrThrMetArgSerProValPheThrAspAsnSerSerProProValValPro
 CTAGAGACAACCAGGGTCCCGGTTACGGATAACTCCTCTCCACCAGTAGTGGCCC
 GATCTCTGTTGGTACTCCAGGGGCCACAAGTGCTATTGAGGAGAGGTGGTCATCACGGG

 3661 GlnSerPheGlnValAlaHisLeuHisAlaProThrGlySerGlyLysSerThrLysVal
 CAGAGCTTCAGGGTGGCTCACCTCCATGCTCCCACAGGCAGCGCAAAGCACCAAGGTC
 GTCTCGAAGGTCCACCAGTAGGGTACGAGGGTGTCCGTCGCCGTTCTGTGGTTCCAG

 3721 ProAlaAlaTyrAlaAlaGlnGlyTyrLysValLeuValLeuAsnProSerValAlaAla
 CCGGCTGCATATGCAGCTCAGGGCTATAAGGTGCTAGTACTCAACCCCTCTGTGCTGCA
 GGCGACGTATACTCGAGTCCGATATTCCACGATCATGAGTTGGGAGACAACGACGT

 3781 ^{Leu} ThrLeuGlyPheGlyAlaTyrMetSerLysAlaHisGlyIleAspProAsnIleArgThr
 ACACTGGGCTTGGTCTACATGTCAGGCTATGGGATCGATCCTAACATCAGGACC
 TGTGACCCGAAACCACGAATGTACAGGTTCCGAGTACCCCTAGCTAGGATTGTAGTCCTGG

 3841 GlyValArgThrIleThrThrGlySerProIleThrTyrSerThrTyrGlyLysPheLeu
 GGGGTGAGAACAAATTACCACTGGCAGCCCCATCACGTACTCCACCTACGGCAAGTCCCTT
 CCCCCACTCTGTTAATGGTGACCGTCGGGTAGTGCATGAGGTGGATGCCGTTCAAGGAA

 3901 AlaAspGlyGlyCysSerGlyGlyAlaTyrAspIleIleIleCysAspGluCysHisSer
 GCCGACGGCGGGTGCTCGGGGGCGTTATGACATAATAATTGTGACGAGTGCCACTCC
 CGGCTGCCGCCACGAGCCCCCGCGAATACTGTATTATAAACACTGCTCACGGTGAGG

 3961 ThrAspAlaThrSerIleLeuGlyIleGlyThrValLeuAspGlnAlaGluThrAlaGly
 ACGGATGCCACATCCATCTGGGCATCGGCACTGTCCTTGACCAAGCAGAGACTGCGGGGG
 TGCCTACGGTGTAGGTAGAACCGTAGCCGTGACAGGAACTGGTCTCTGACGCC

 4021 AlaArgLeuValValLeuAlaThrAlaThrProProGlySerValThrValProHisPro
 GCGAGACTGGTTGTGCTCGCCACCGCCACCCCTCCGGCTCGTCACTGTGCCCATCCC
 CGCTCTGACCAACACGAGCGGTGGCGGTGGGAGGCCGAGGCAGTGACACGGGTAGGG

 4081 AsnIleGluGluValAlaLeuSerThrThrGlyGluIleProPheTyrGlyLysAlaIle
 AACATCGAGGAGGTTGCTCTGTCCACCCGGAGAGATCCCTTTACGGCAAGGCTATC
 TTGTAGCTCCTCCAACGAGACAGGTGGTGGCCTCTAGGGAAAATGCCGTTCCGATAG

 4141 ProLeuGluValIleLysGlyGlyArgHisLeuIlePheCysHisSerLysLysLysCys
 CCCCTCGAAGTAATCAAGGGGGGAGACATCTCATCTCTGTCAATTCAAAGAAGAAGTGC
 GGGGAGCTTCATTAGTTCCCCCCTCTGTAGAGTAGAACAGACTAACAGTTCTTCAG

 4201 AspGluLeuAlaAlaLysLeuValAlaLeuGlyIleAsnAlaValAlaTyrTyrArgGly
 GACGAACTCGCCGAAAGCTGGTCGCATTGGGCATCAATGCCGTGGCCTACTACCGCGGT
 CTGCTTGAGCGGGTTTCGACCAGCGTAACCGTAGTTACGGCACCGGATGATGGCGCCA

 4261 LeuAspValSerValIleProThrSerGlyAspValValValAlaThrAspAlaLeu
 CTTGACGTGTCCGTACCCGACCAGCGCGATGTTGTCGTGGCAACCGATGCCCTC
 GAACTGCACAGGCAGTAGGGCTGGTCGCCGCTACAACAGCAGCACCGTTGGCTACGGGAG

 4321 ^{Tyr} MetThrGlyTyrThrGlyAspPheAspSerValIleAspCysAsnThrCysValThrGln
 ATGACCGGGCTATACCGGCGACTTCGACTCGGTGATAGACTGCAATACGTGTGTCACCCAG
 TACTGGCCGATATGGCGCTGAAGCTGAGCCACTATCTGACGTTATGCACACAGTGGGT

 4381 ^{Ser} ThrValAspPheSerLeuAspProThrPheThrIleGluThrIleThrLeuProGlnAsp
 ACAGTCGATTTCAGCCTTGACCCCTACCTCACCATTGAGACAATCACGCTCCCCCAGGAT
 TGTCAGCTAAAGTCGGAACCTGGGATGGAAGTGGTAACTCTGTAGTGCAGGGGGTCCTA

 4441 AlaValSerArgThrGlnArgArgGlyArgThrGlyArgGlyLysProGlyIleTyrArg
 GCTGTCTCCCGACTCAACGTCGGGGCAGGACTGGCAGGGGGAAAGCCAGGCATCTACAGA
 CGACAGAGGGCGTGAGTTGCAGCCCCGTCCTGACCGTCCCCCTCGGTCCGTAGATGTCT

 4501 PheValAlaProGlyGluArgProSerGlyMetPheAspSerSerValLeuCysGluCys
 TTTGTGGCACCGGGGGAGCGCCCCCTCCGGCATGTTGACTCGTCCGTCTGTGAGTGC
 AACACCGTGGCCCCCTCGCGGGAGGCCGTACAAGCTGAGCAGGCAGGAGACACTCACG

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FIG. 17-6

4561 TyrAspAlaGlyCysAlaTrpTyrGluLeuThrProAlaGluThrThrValArgLeuArg
 TATGACGCAGGCTGTGCTTGGTATGAGCTCACGCCGCCGAGACTACAGTTAGGCTACGA
 ATACTCGTCCGACACGAACCATACTCGAGTGCAGGGCTCTGATGTCATCCGATGCT

 4621 AlaTyrMetAsnThrProGlyLeuProValCysGlnAspHisLeuGluPheTrpGluGly
 GCGTACATGAACACCCCGGGCTTCCCGTGCCAGGACCATTTGAATTGGGAGGGC
 CGCATGTTACTTGAGGGCCACACGGCCTGGTAGAACTTAAACCCCTCCCG

 4681 ValPheThrGlyLeuThrHisIleAspAlaHisPheLeuSerGlnThrLysGlnSerGly
 GTCTTACAGGCCTCACTCATATAGATGCCACTTCTATCCCAGACAAAGCAGAGTGGG
 CAGAAATGTCGGAGTGAATCTACGGTGAAAGATAGGGCTGTTCGTCAACCC

 4741 GluAsnLeuProTyrLeuValAlaTyrGlnAlaThrValCysAlaArgAlaGlnAlaPro
 GAGAACCTTCCTTACCTGGTAGCGTACCAAGCCACCGTGTGGCTAGGGCTCAAGCC
 CTCTTGGAAAGGAATGGACCATCGCATGGTGGCACACGGATCCGAGTCGGGA

 4801 ProProSerTrpAspGlnMetTrpLysCysLeuIleArgLeuLysProThrLeuHisGly
 CCCCCATCGTGGGACCAGATGTGGAAAGTGTGTTGATTGCTACGCCCTGACGCACCC
 GGGGGTAGCACCCCTGGTCTACACCTTCACAAACTAACGGAGTTGGGAGTCGGTACCC

 4861 ProThrProLeuLeuTyrArgLeuGlyAlaValGlnAsnGluIleThrLeuThrHisPro
 CCAACACCCCTGCTATACAGACTGGGCGCTGTTCAAATGAAATCACCTGACGCACCC
 GGTGTTGGGGACGATATGTGACCCCGACAAGTCTACTTGTGGGACTGCGTGGGT

 4921 ValThrLysTyrIleMetThrCysMetSerAlaAspLeuGluValValThrSerThrTrp
 GTCACCAAATACATCATGACATGCATGCGGCCGACCTGGAGGTCGTACGAGCACCTGG
 CAGTGGTTATGTAGTACTGTACAGCAGGCTGGACCTCCAGCAGTGCTCGTGGACC

 4981 ValLeuValGlyGlyValLeuAlaAlaLeuAlaAlaTyrCysLeuSerThrGlyCysVal
 GTGCTCGTIGGCGCGTCTGGCTGTTGGCCGCGTATTGCTGCAACAGGCTGCGT
 CACGAGCAACCGCCGAGGACCGACGAAACCGGCGATAACGGACAGTTGCTCCGACGCAC

 5041 ValIleValGlyArgValValLeuSerGlyLysProAlaIleIleProAspArgGluVal
 GTCATAGTGGGCAAGGGTCTCTGTCCTGCGCTACGACTTACCGTACATCGAGCAA
 CAGTATCACCCGCTCCAGCAGAACAGGCCCTCGGCCGTTAGTATGGACTGTCCTCAG

 5101 LeuTyrArgGluPheAspGluMetGluGluCysSerGlnHisLeuProTyrIleGluGln
 CTCTACCGAGAGTCGATGAGATGAAAGAGTGCCTCAGCACTTACCGTACATCGAGCAA
 GAGATGGCTCTCAAGCTACTCACCTCTCACGAGAGTCGTAAATGGCATGTTAGCTCGTT

 5161 GlyMetMetLeuAlaGluGlnPheLysGlnLysAlaLeuGlyLeuLeuGlnThrAlaSer
 GGGATGATGCTCGCCGAGCAGTTCAAGCAGAACGCCCTCGGCCCTGAGACCGCGTCC
 CCCTACTACGAGCGGCTCGTCAAGTTGCTTCCGGGAGCCGGAGGACGCTGGCGCAGG

 5221 ArgGlnAlaGluValIleAlaProAlaValGlnThrAsnTrpGlnLysLeuGluThrPhe
 CGTCAGGCAGAGTTATGCCCTGCTGTCAGACCAACTGGCAAAACTCGAGACCTTC
 GCAGTCCGTCTCCAATAGCGGGGACGACAGGTCTGGTTGACCGTTTGAGCTCTGGAAAG

 5281 TrpAlaLysHisMetTrpAsnPheIleSerGlyIleGlnTyrLeuAlaGlyLeuSerThr
 TGGGCGAAGCATATGTGGAACTTCATCAGTGGGATAACAATCTGGGGCTTGTCAACG
 ACCCGCTCGTATACACCTTGAAAGTAGTCACCCATGTTATGAACCGCCGAACAGTTGC

 5341 LeuProGlyAsnProAlaIleAlaSerLeuMetAlaPheThrAlaAlaValThrSerPro
 CTGCCTGGTAACCCGCCATTGCTTCATTGATGGCTTTACAGCTGCTGTCACCAGCCA
 GACGGACCATGGGGCGGTAAACGAAGTAACCGAAAATGTCGACGACAGTGGTCGGGT

 5401 LeuThrThrSerGlnThrLeuLeuPheAsnIleLeuGlyGlyTrpValAlaAlaGlnLeu
 CTAACCACTAGCCAAACCCCTCCCTTCACATATTGGGGGGTGGGTGGCTGCCAGCTC
 GATTGGTGATCGGTTGGGAGGAGAAGTTGTATAACCCCCCACCACCGACGGGTGAG

 5461 AlaAlaProGlyAlaAlaThrAlaPheValGlyAlaGlyLeuAlaGlyAlaAlaIleGly
 GCCGCCCGGTGCCGCTACTGCCTTGTGGCGCTGGCTTAGCTGGCGCCGCCATCGGC
 CGGGGGGCCACGGCAGACGGAAACACCCCGCAGCGAACGAAATGACCGCGGGTAGCCG

 SerValGlyLeuGlyLysValLeuIleAspIleLeuAlaGlyTyrGlyAlaGlyValAla

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FIG. 17-7

5521 AGTGTGGACTGGGAAGGTCTCATAGACATCTTGCAGGGTATGGCGCGGGCGTGGCG
TCACAAACCTGACCCCTTCAGGAGTATCTGTAGGAACGTCCCATAACCGCGCCCGACCGC

5581 GlyAlaLeuValAlaPheLysIleMetSerGlyGluValProSerThrGluAspLeuVal
GGAGCTCTTGTGGCATTCAAGATCATGAGCGGTGAGGTCCCCTCACGGAGGACCTGGTC
CCTCGAGAACACCGTAAGTTCTAGTACTCGCCACTCCAGGGGAGGTGCCTCTGGACCAG

5641 AsnLeuLeuProAlaIleLeuSerProGlyAlaLeuValValGlyValValCysAlaAla
AATCTACTGCCGCCATCTCGCCGGAGCCCTCGTAGTCGGCGTGGTCTGTGCAGCA
TTAGATGACGGCGGTAGGAGAGCGGGCCTCGGGAGCATCAGCCGACCAGACACGTCGT

5701 IleLeuArgArgHisValGlyProGlyGluGlyAlaValGlnTrpMetAsnArgLeuIle
ATACTGCGCCGGCACGGTGGCCCGGGCAGTGCAGTGGATGAACCGGCTGATA
TATGACGCGGCCGTGCAACCAGGGCCGCTCCCCCGTACGTCACCTACTGGCCGACTAT

5761 AlaPheAlaSerArgGlyAsnHisValSerProThrHisTyrValProGluSerAspAla
GCCTTCGCCTCCGGGGAAACCATGTTCCCCACGCACTACGTGCCGGAGAGCGATGCA
CGGAAGCGGAGGGCCCTGGTACAAAGGGGTGCGTATGACCGCCCTCGCTACGT

5821 HisCys
AlaAlaArgValThrAlaIleLeuSerSerLeuThrValThrGlnLeuLeuArgArgLeu
GCTGCCCGCGTCACTGCCATACTCAGCAGCCTCACTGTAACCCAGCTCTGAGGCGACTG
CGACGGCGCAGTGACGGTATGAGTCGTCGGAGTGACATTGGTCGAGGACTCCGCTGAC

5881 HisGlnTrpIleSerSerGluCysThrThrProCysSerGlySerTrpLeuArgAspIle
CACCAAGTGGATAAGCTCGGAGGTGACCTCCATGCTCCGGTCTGGCTAAGGGACATC
GTGGTCACCTATTGAGCCTCACATGGTGGAGGTACGAGGCCAAGGACCGATTCCCTGTAG

5941 TrpAspTrpIleCysGluValLeuSerAspPheLysThrTrpLeuLysAlaLysLeuMet
TGGGACTGGATATGCGAGGTGTTGAGCGACTTTAAGACCTGGCTAAAGCTAACGTCATG
ACCCTGACCTATACTGCTCCACAACCTCGCTGAAATTCTGGACCGATTTGATTGAGTAC

6001 ProGlnLeuProGlyIleProPheValSerCysGlnArgGlyTyrLysValTrpArg
CCACAGCTGCCTGGATCCCTTTGTCCTGCCAGCGCGGGTATAAGGGGTCTGGCGA
GGTGTGACGGACCCTAGGGGAAACACAGGACGGTCGCCATATTCCCCCAGACCGCT

6061 Gly
ValAspGlyIleMetHisThrArgCysHisCysGlyAlaGluIleThrGlyHisValLys
GTGGACGGCATCATGCACACTCGCTGCCACTGTGGAGCTGAGATCACTGGACATGTCAAA
CACCTGCCGTAGTACGTGTGAGCGACGGTGACACCTCGACTCTAGTGACCTGTACAGTT

6121 AsnGlyThrMetArgIleValGlyProArgThrCysArgAsnMetTrpSerGlyThrPhe
AACGGGACGATGAGGATCGTCGGCTCTAGGACCTGCAGGAACATGTGGAGTGGACCTTC
TTGCCCTGCTACTCCCTAGCAGCCAGGATCCTGGACGTCCTGTACACCTCACCTGGAAAG

6181 ProIleAsnAlaTyrThrThrGlyProCysThrProLeuProAlaProAsnTyrThrPhe
CCCATTAAATGCCCTACACCACGGGCCCTGTACCCCTTCCTGCCCGAACTACACGTT
GGGTAATTACGGATGTGGTGCCCGGGACATGGGGGAAGGACGCGGCTTGATGTGCAAG

6241 AlaLeuTrpArgValSerAlaGluGluTyrValGluIleArgGlnValGlyAspPheHis
GCGCTATGGAGGGTGTCTGCAGAGGAATATGTGGAGATAAGGCAGGTGGGGACTCCAC
CGCGATAACCTCCCACAGACGTCTCCTTATACACCTCTATTCCGTCCACCCCTGAAGGTG

6301 TyrValThrGlyMetThrThrAspAsnLeuLysCysProCysGlnValProSerProGlu
TACGTGACGGGTATGACTACTGACAATCTCAAATGCCGTGCCAGGTCCCCTGCCGAA
ATGCACTGCCCATACTGATGACTGTTAGGTTACGGGACGGTCCAGGGTAGCGGGCTT

6361 PhePheThrGluLeuAspGlyValArgLeuHisArgPheAlaProProCysLysProLeu
TTTTCACAGAATTGGACGGGGTGCCTACATAGGTTGCGCCCCCTGCAAGCCCTTG
AAAAAGTGTCTAACCTGCCACGCGGATGTATCCAAACGCGGGGGACGTTCGGGAAAC

6421 LeuArgGluGluValSerPheArgValGlyLeuHisGluTyrProValGlySerGlnLeu
CTGCGGGAGGAGGTATCATTAGAGTAGGACTCCACGAATACCGGTAGGGTCGCAATT
GACGCCCTCCTCCATAGTAAGTCTCATCCTGAGGTGCTTATGGGCCATCCCAGCGTTAAT

FIG. 17-8

6481 ProCysGluProGluProAspValAlaValLeuThrSerMetLeuThrAspProSerHis
 CCTTGCAGCCCCAACGGACGTGGCGTGTGACGTCCATGCTCACTGATCCCTCCCAT
 GGAACGCTCGGGCTTGGCCTGCACCAGCACACTGCAGGTACGAGTGAAGGGAGGGTA

 6541 IleThrAlaGluAlaAlaGlyArgArgLeuAlaArgGlySerProProSerValAlaSer
 ATAACAGCAGGGCGCCGGCGAAGGTTGGCGAGGGATACCCCCCTCTGTGGCCAGC
 TATTGTCGTCTCCGCCGGCCGCTTCCAACCGCTCCCTAGTGGGGGAGACACCGGTCG

 6601 SerSerAlaSerGlnLeuSerAlaProSerLeuLysAlaThrCysThrAlaAsnHisAsp
 TCCTCGGCTAGCCAGCTATCCGCTCCATCTCAAGGCAACTTGCACCGCTAACCATGAC
 AGGAGCCGATCGTCGATAGCGAGGTAGAGAGTTCCGTTGAACGTGGCGATTGGTACTG

 6661 SerProAspAlaGluLeuIleGluAlaAsnLeuLeuTrpArgGlnGluMetGlyGlyAsn
 TCCCCTGATGCTGAGCTCATAGAGGCCAACCTCTATGGAGGAGATGGCGGCAAC
 AGGGGACTACGACTCGAGTATCTCCGGTTGGAGGATACTCCGCTCTACCCGCCGTTG

 6721 IleThrArgValGluSerGluAsnLysValValIleLeuAspSerPheAspProLeuVal
 ATCACCAAGGGTTGAGTCAGAAAACAAAGTGGTATTCTGGACTCCTCGATCCGTTGTG
 TAGTGGTCCCAACTCAGTCTTGTGTTACCACTAAGACCTGAGGAAGCTAGGCGAACAC

 6781 AlaGluGluAspGluArgGluIleSerValProAlaGluIleLeuArgLysSerArgArg
 GCGGAGGGAGGACGAGCGGGAGATCTCGTACCCGAGAAATCTGCGGAAGTCTCGGAGA
 CGCCTCCTCTGCTCGCCCTCTAGAGGCATGGCGTCTTAGGACGCCTCAGAGCCTCT

 6841 PheAlaGlnAlaLeuProValTrpAlaArgProAspTyrAsnProProLeuValGluThr
 TTGCCCCAGGCCCTGCCGTTGGCGCGCCGACTATAACCCCCCGTAGTGGAGACG
 AAGCGGGTCCGGGACGGGAAACCCGCGCCGGCCTGATATTGGGGGGGATCACCTCTGC

 6901 TrpLysLysProAspTyrGluProProValValHisGlyCysProLeuProProProLys
 TGGAAAAAGCCGACTACGAACCACCTGTGGTCCATGGCTGCGCTCCACCTCAAAG
 ACCTTTTCGGGCTGATGCTGGTGACACCAGGTACCGACAGGCGAAGGTGGAGGTTTC

 6961 SerProProValProProProArgLysLysArgThrValValLeuThrGluSerThrLeu
 TCCCCTCTGTGCCCTCGGCCTCGGAAGAAGCGGACGGTGGCCTCACTGAATCAACCTA
 AGGGGAGGACACGGAGGCGGAGCCTCTCGCCTGCCACCAGGAGTGACTTAGTTGGGAT

 7021 SerThrAlaLeuAlaGluLeuAlaThrArgSerPheGlySerSerSerThrSerGlyIle
 TCTACTGCCCTGGCGAGCTGCCACCAGAAAGCTTGGCAGCTCCTCAACTCCGGCATT
 AGATGACGGAACCGGCTCGAGCGGTGGTCTCGAAACCGTCGAGGAGTTGAAGGCCGTA

 7081 ThrGlyAspAsnThrThrSerSerGluProAlaProSerGlyCysProProAspSer
 ACGGGCGACAATACGACAACATCCTCTGAGCCGCCCTCTGGCTGCCCCCCGACTCC
 TGCCCGCTGTATGCTGTGTTAGGAGACTCGGGCGGGGAAGACCGACGGGGGGCTGAGG

 PheAla
 7141 AspAlaGluSerTyrSerSerMetProProLeuGluGlyGluProGlyAspProAspLeu
 GACGCTGAGTCCTATTCCCATGCCCTGGAGGGGGAGCCTGGGGATCCGGATCTT
 CTGCGACTCAGGATAAGGAGGTACGGGGGGACCTCCCCCTCGGACCCCTAGGCCTAGAA

 7201 SerAspGlySerTrpSerThrValSerSerGluAlaAsnAlaGluAspValValCysCys
 AGCGACGGGTCTGGACACGGCGCACTCGTCAGTAGTGAGGCCAACGCGGAGGATGTCGTGCTGC
 TCGCTGCCAGTACCAAGTGCAGTCAGTCACTCCGGTTGCGCCTCTACAGCACACGACG

 7261 SerMetSerTyrSerTrpThrGlyAlaLeuValThrProCysAlaAlaGluGlnLys
 TCAATGCTTACTCTGGACAGGGCGCACTCGTCACCCGTGCGCCGCGGAAGAACAGAAA
 AGTTACAGAATGAGAACCTGTCCCGGTGAGCAGTGGGCACGCCGCGCTTCTGTCTT

 7321 LeuProIleAsnAlaLeuSerAsnSerLeuLeuArgHisHisAsnLeuValTyrSerThr
 CTGCCCATCAATGCAACTAGCAACTCGTTGCTACGTCACTGACCAAAATTGGGTATTCCACC
 GACGGGTAGTTACGTGATTGTTGAGCAACGATGCACTGGTGTAAACCACATAAGGTGG

 7381 ThrSerArgSerAlaCysGlnArgGlnLysLysValThrPheAspArgLeuGlnValLeu
 ACCTCACCGCAGTGCTTGCCTAACGGCAGAAGAAAGTCACATTGACAGACTGCAAGTTCTG
 TGGAGTGCCTCACGAAACGGTTCCGTTCTCAGTGTAAACTGTCAGTCAAGAC

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FIG. 17-9

7441 AspSerHisTyrGlnAspValLeuLysGluValLysAlaAlaAlaSerLysValLysAla
GACAGCCATTACCAGGACGTACTCAAGGAGGTTAAAGCAGCGCGTCAAAAGTGAAGGCT
CTGTCGGTAATGGTCCTGCATGAGTTCCTCAATTCTCGCCGCAGTTTCACCTCCGA

Phe

7501 AsnLeuLeuSerValGluGluAlaCysSerLeuThrProProHisSerAlaLysSerLys
AACTTGCTATCCGTAGAGGAAGCTGCAGCCTGACGCCAACACTCAGCAAATCCAAG
TTGAACGATAGGCATCTCCTCGAACGTCGGACTCGGGGGTGTGAGTCGGTTAGGTTC

7561 PheGlyTyrGlyAlaLysAspValArgCysHisAlaArgLysAlaValThrHisIleAsn
TTTGGTTATGGGGCAAAAGACGTCCGTTGCCATGCCAGAAAGGCCGTAACCCACATCAAC
AAACCAATAACCCGTTTCTGCAGGCAACGGTACGGTCTTCCGGCATTGGGTGTAGTTG

7621 SerValTrpLysAspLeuLeuGluAsnValThrProIleAspThrThrIleMetAla
TCCGTGTTGGAAAGACCTTCTGGAAGACAATGTAACACCAATAGACACTACCACATGGCT
AGGCACACCTTCTGGAAGACCTTCTGTTACATTGTGGTTATCTGTGATGGTAGTACCGA

7681 LysAsnGluValPheCysValGlnProGluLysGlyGlyArgLysProAlaArgLeuIle
AAGAACGAGGTTTCTGCGTTAGCCTGAGAAGGGGGTCGTAAGCCAGCTCGTCATC
TTCTGCTCCAAAAGACGCAAGTCGGACTCTCCCCCAGCATTGGTCGAGCAGAGTAG

7741 ValPheProAspLeuGlyValArgValCysGluLysMetAlaLeuTyrAspValValThr
GTGTTCCCCGATCTGGCGTGCCTGCGTGTGCGAAAAGATGGCTTGTACGACGTGGTTACA
CACAAAGGGCTAGACCCGACGCGCACACGCTTCTACCGAAACATGCTGCACCAATGT

7801 LysLeuProLeuAlaValMetGlySerSerTyrGlyPheGlnTyrSerProGlyGlnArg
AAGCTCCCTTGGCCGTGATGGGAAGCTCCTACGGATTCCAATACTCACCAGGACAGCGG
TTCGAGGGAAACCGGCACTACCCTCGAGGATGCTAAAGTTATGAGTGGTCCTGCGCC

7861 ValGluPheLeuValGlnAlaTrpLysSerLysLysThrProMetGlyPheSerTyrAsp
GTTGAATTCTCGTGCAAGCGTGGAAAGTCCAAGAAAACCCAAATGGGGTTCTGCTATGAT
CAACTTAAGGAGCACGTTGCACCTTCAGGTTCTTGGGGTTACCCAAGAGCATACTA

7921 ThrArgCysPheAspSerThrValThrGluSerAspIleArgThrGluGluAlaIleTyr
ACCCGCTGCTTGACTCCACAGTCACTGAGAGCGACATCCGTACGGAGGAGGCAATCTAC
TGGCGACAAACTGAGGTGTCAGTGACTCTCGCTGTAGGCATGCCTCCGTTAGATG

7981 GlnCysCysAspLeuAspProGlnAlaArgValAlaIleLysSerLeuThrGluArgLeu
CAATGTGTGACCTCGACCCCCAAGCCCGTGGCCATCAAGTCCCTACCGAGAGGCTT
GTTACAACACTGGAGCTGGGGTTGGCGCACCGTAGTTCAAGGAGTGGCTCTCCGAA

Gly

8041 TyrValGlyGlyProLeuThrAsnSerArgGlyGluAsnCysGlyTyrArgArgCysArg
TATGTTGGGGGCCCTTACCAATTCAAGGGGGAGAACTGCGGCTATCGCAGGTGCCGC
ATACAACCCCCGGGAGAATGGTTAAGTCCCCCTTGACGCCGATAGCGTCCACGGCG

8101 AlaSerGlyValLeuThrThrSerCysGlyAsnThrLeuThrCysTyrIleLysAlaArg
GCGAGCGCGTACTGACAACTAGCTGTGTAACACCCCTCACTGCTACATCAAGGCCGG
CGCTCGCCGATGACTGTTGATCGACACCATTGTGGAGTGAACGATGTAGTCCGGGCC

8161 AlaAlaCysArgAlaAlaGlyLeuGlnAspCysThrMetLeuValCysGlyAspAspLeu
GCAGCCTGTCGAGCCGCAGGGCTCCAGGACTGCACCATGCTCGTGTGGCGACGACTTA
CGTCGGACAGCTGGCGTCCCGAGGTCTGACGTGGTACGAGCACACACCGCTGCTGAAT

8221 ValValIleCysGluSerAlaGlyValGlnGluAspAlaAlaSerLeuArgAlaPheThr
GTCGTTATCTGTGAAAGCGCGGGGTCCAGGAGGACGCCGAGCCTGAGAGCCTCAGC
CAGCAATAGACACTTCGCGCCCCAGGTCTCGCCGCTCGACTCTCGGAAGTGC

8281 GluAlaMetThrArgTyrSerAlaProProGlyAspProProGlnProGluTyrAspLeu
GAGGCTATGACCAGGTACTCCGCCCCCTGGGACCCCCCAACACAGAACGACTTG
CTCCGATACTGGTCATGAGGCGGGGGACCCCTGGGGGTGTTGGTCTATGCTGAAC

8341 GluLeuIleThrSerCysSerSerAsnValSerValAlaHisAspGlyAlaGlyLysArg
GAGCTCATAACATCATGCTCCTCAACGTGTCAGTCGGCCACGACGGCGCTGGAAAGAGG
CTCGAGTATTGTAGTACGAGGAGGTTGACAGTCAGCGGGTGCCTGCCGCACCTTCCTCC

8401 ValTyrTyrLeuThrArgAspProThrThrProLeuAlaArgAlaAlaTrpGluThrAla
GTCTACTACCTCACCCGTGACCTACAAACCCCCCTCGCGAGAGCTGCGTGGGAGACAGCA
CAGATGATGGAGTGGGACTGGGATGTTGGGGGAGCGCTCTGACGCACCCTGTCGT

8461 ArgHisThrProValAsnSerTrpLeuGlyAsnIleIleMetPheAlaProThrLeuTrp
AGACACACTCCAGTCATTCTGGCTAGGCAACATAATCATGTTGCCCTCACACTGTGG
TCTGTGTGAGGTCAAGGACCGATCCGTTGATTAGTACAAACGGGGTGTGACACC

8521 AlaArgMetIleIleLeuMetThrHisPhePheSerValLeuIleAlaArgAspGlnLeuGlu
GCGAGGATGATACTGATGACCCATTCTTAGCGTCCTTATAGCCAGGGACCAGCTTGAA
CGCTCCTACTATGACTACTGGTAAAGAAATCGCAGGAATATCGGTCCCTGGTCGAACCT

8581 GlnAlaLeuAspCysGluIleTyrGlyAlaCysTyrSerIleGluProLeuAspLeuPro
CAGGCCCTCGATTGCGAGATCTACGGGCCTGCTACTCCATAGAACCACTTGATCTACCT
GTCCGGGAGCTAACGCTCTAGATGCCCGGACGATGAGGTATCTGGTGAAGTAGATGGA

8641 ProIleIleGlnArgLeuHisGlyLeuSerAlaPheSerLeuHisSerTyrSerProGly
CCAATCATTCAAAGACTCCATGGCCTCAGCGCATTTCACTCCACAGTTACTCTCCAGGT
GGTTAGTAAGTTCTGAGGTACCGGAGTCGCGTAAAGTGAGGTGTCAATGAGAGGTCCA

8701 GluIleAsnArgValAlaAlaCysLeuArgLysLeuGlyValProProLeuArgAlaTrp
GAAATTAAATAGGGTGGCCGCATGCCTCAGAAAACCTGGGGTACCGCCCTTGCAGCTTGG
CTTTAATTATCCCACCGCGTACGGAGTCTTGAACCCATGGCGGGAACGCTCGAAC
Gly
ArgHisArgAlaArgSerValArgAlaArgLeuLeuAlaArgGlyGlyArgAlaAlaIle
8761 AGACACCGGGCCCGGAGCGTCCCGCCTAGGCTCTGGCCAGAGGAGGCAGGGCTGCCATA
TCTGTGGCCCAGGCGTACCGCAGGCGATCCGAAGACCGGTCTCCGTCCCGACGGTAT

8821 CysGlyLysTyrLeuPheAsnTrpAlaValArgThrLysLeuLys
TGTGGCAAGTACCTCTTCAACTGGGAGTAAGAACAAAGCTCAAAC
ACACCGTTCATGGAGAAGTTGACCCGTCTTGTGAGTTG

FIG. 17-10

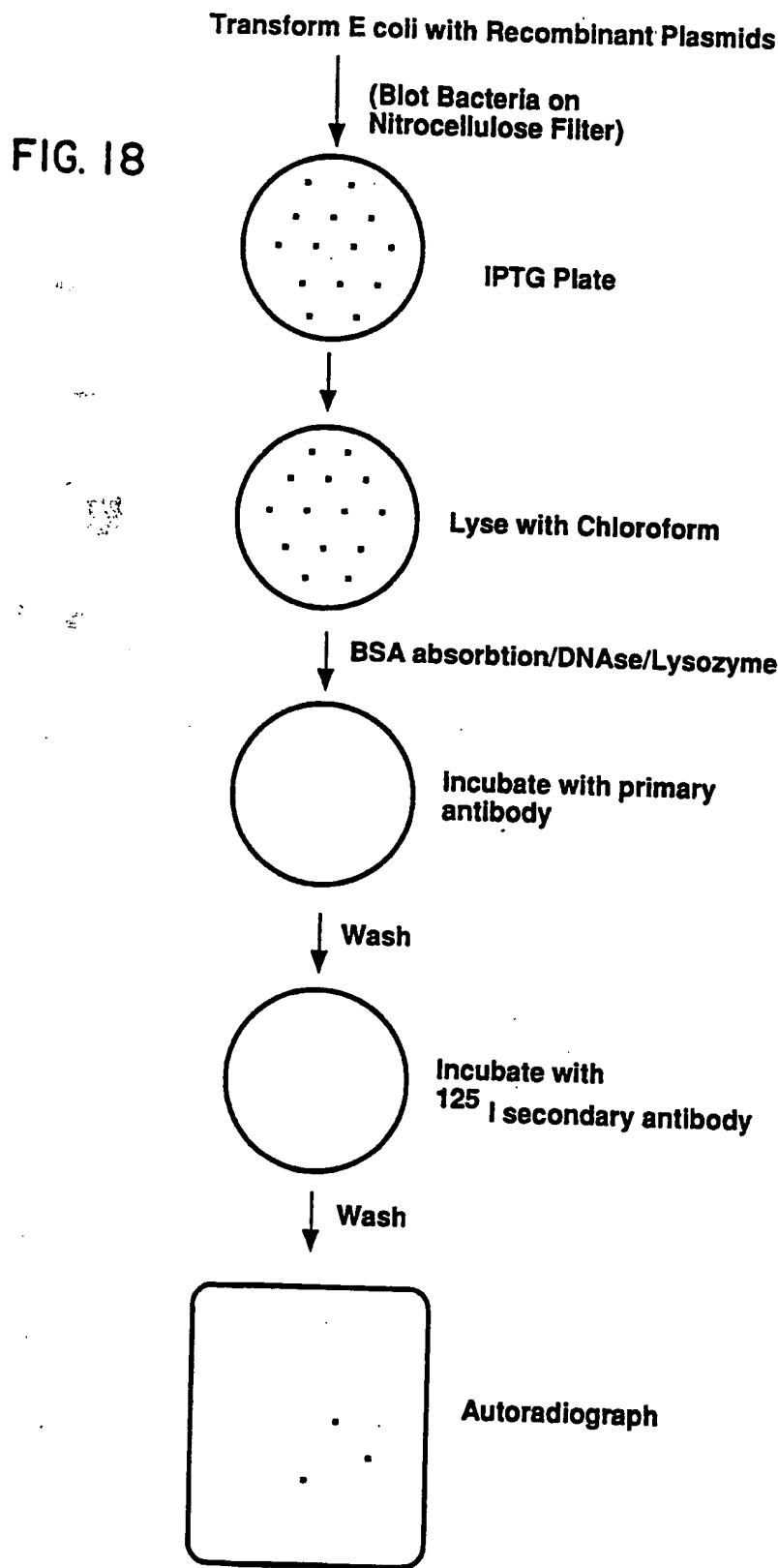
IMMUNOLOGICAL SCREENING IN BACTERIA

FIG.19-1

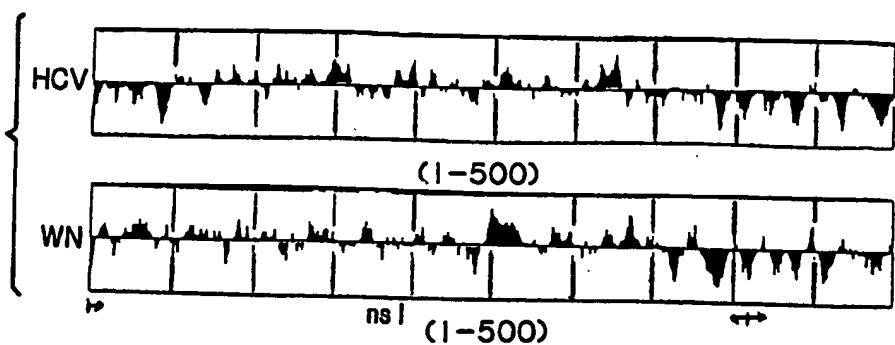


FIG.19-2

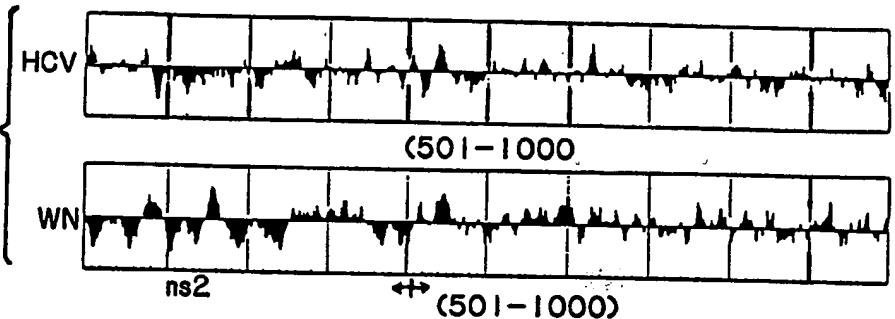


FIG.19-3

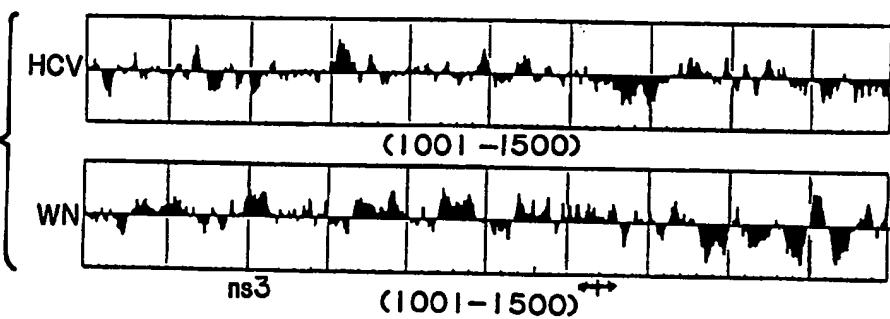


FIG.19-4

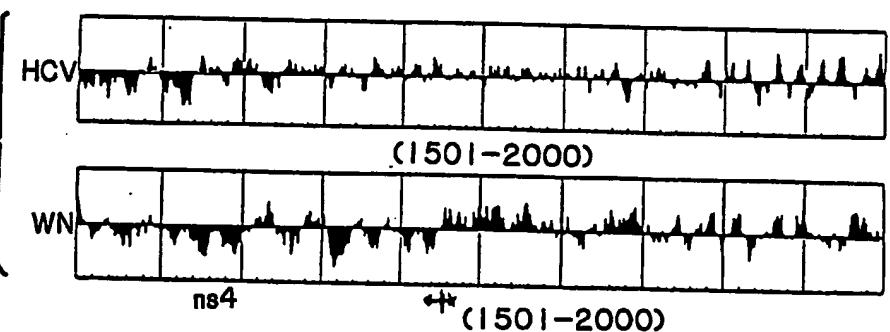
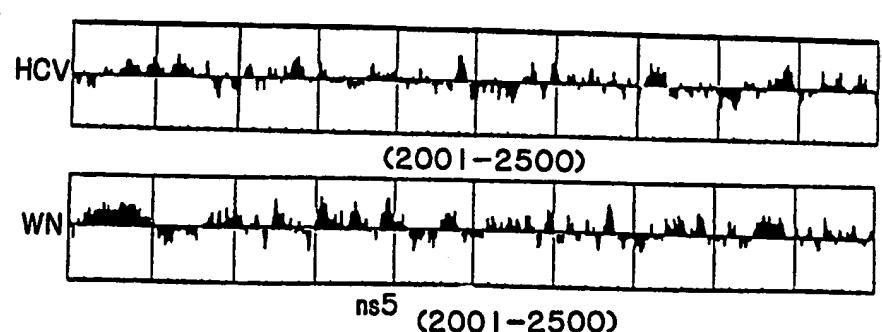
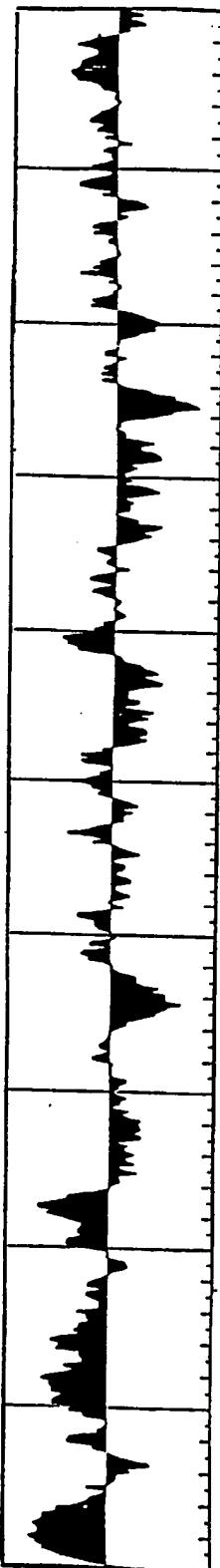


FIG.19-5



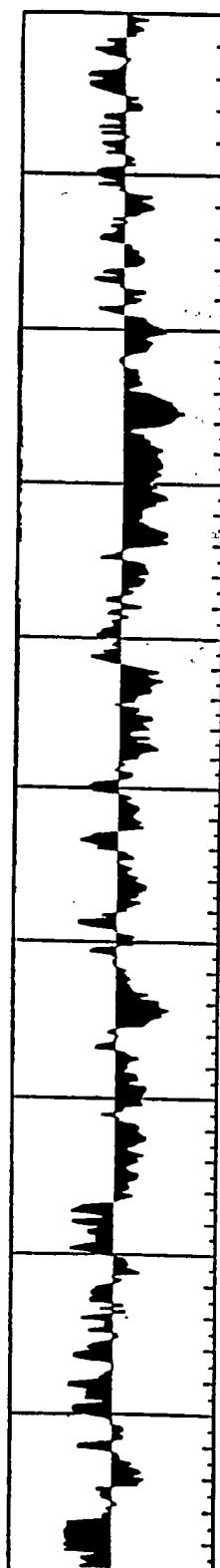
HYDROPHILIC FIG. 20 - 1



ANTIG INDEX

HCV (1 - 500)

HYDROPHILIC FIG. 20 - 2

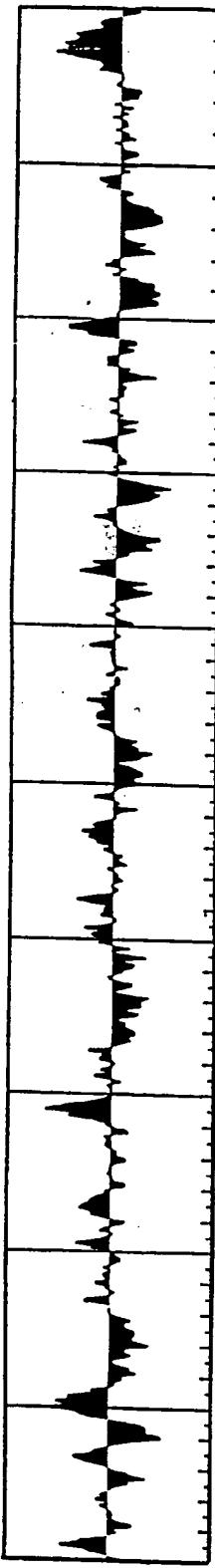


ANTIG INDEX

HCV (501 - 1000)

SUBSTITUTE SHEET

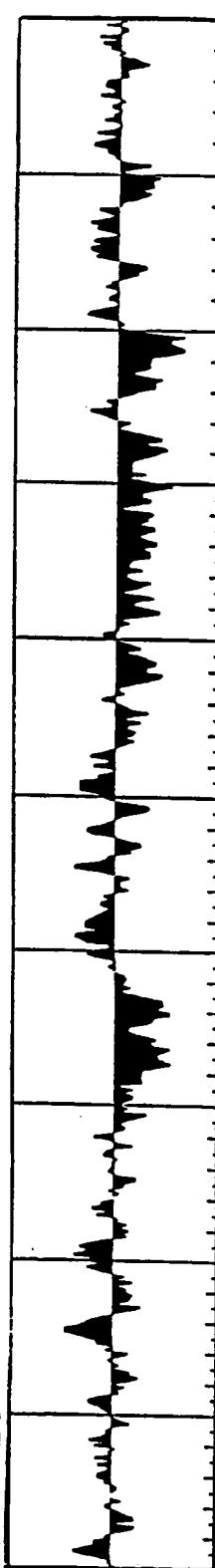
HYDROPHILIC FIG. 20-3



ANTIG INDEX

HCV (1001 - 1500)

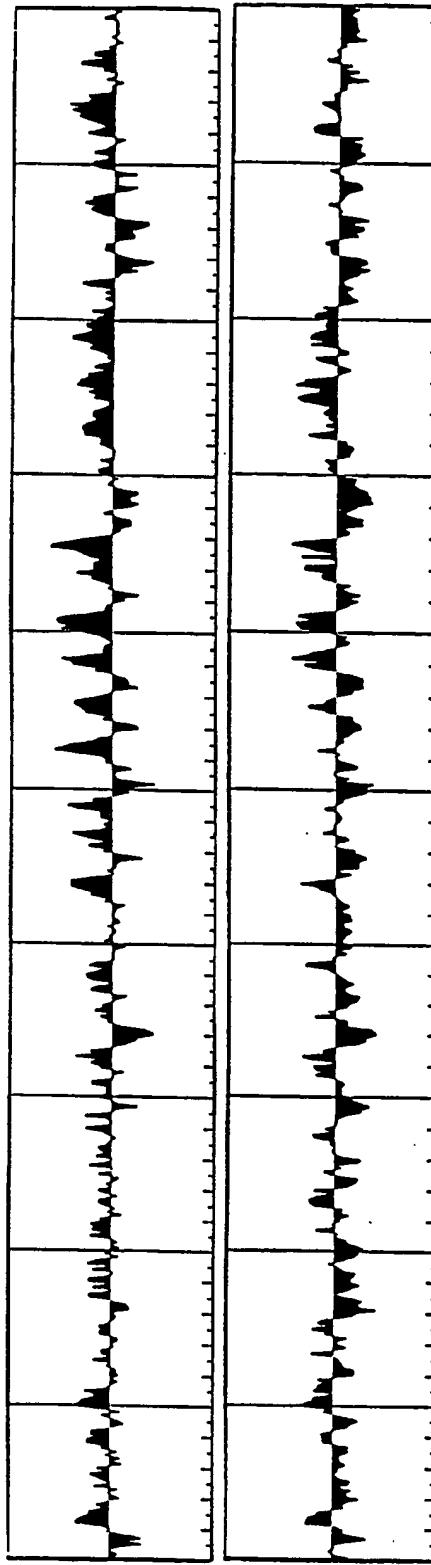
HYDROPHILIC FIG. 20-4



ANTIG INDEX

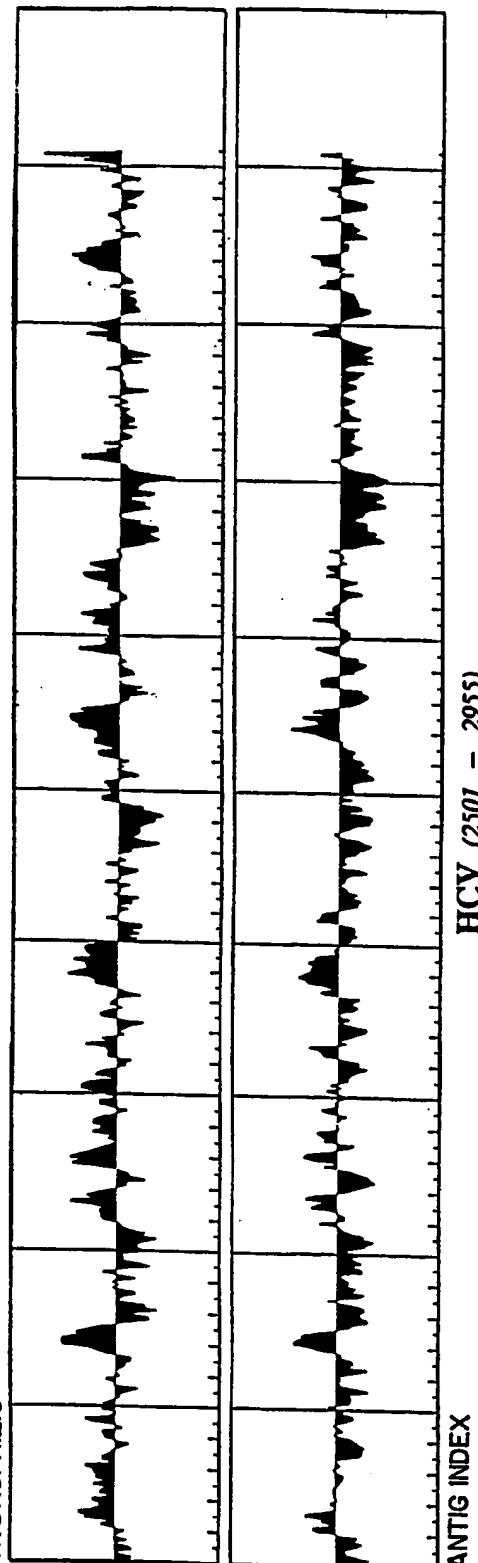
HCV (1501 - 2000)

HYDROPHILIC FIG. 20-5



HYDROPHILIC

FIG. 20-6



ANTIG INDEX

HCV (2501 - 2955)

Some conserved co-linear peptides in HCV & Flaviviruses

NS5
Highly-conserved
Polymerase
region

NS3 region

Flaviviruses (Yellow Fever, West Nile, Dengue)

HCV

***** * ***** * * * * *

#1348 #1483 #2737

FIG. 21

SUBSTITUTE SHEET

INTERNATIONAL SEARCH REPORT

International Application No. PCT/US90/01348

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(5):A61K 39/12;C07H 21/04;C07K 7/06,08,10,13/00,15/28;
US: 536/27;435/6,7,69.1,320,240.1;530/324-327,350,387,416;424/89

II. FIELDS SEARCHED

see attachment

Minimum Documentation Searched ⁷

Classification System	Classification Symbols
U.S.	536/27;435/6,7,69.1,320,240.1 530/324-327,350,387,416; 424/89

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched ⁸

Automated Patent Search, Chemical Abstract Service

III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A, P	US, A, 4,870,026 WANDS ET AL. 26 September 1989	1-34
A	US, A, 4,702,909 VILLAREJOS ET AL. 27 October 1987	1-34
A	US, A, 4,542,016 TREPO 17 September 1985	1-34
X, P	Science, "Isolation of a c DNA clone derived from a blood-borne non-A, non-B viral hepatitis genome" volume 244, pp 359-362. CHOO ET AL. 21 April 1989 see abstract & figs.	1-12,15,16, 18-20,22,28-31,33
X, P	Science, "An assay for circulating antibodies to a major eholologic virus of human nonA,nonB Hepatitis" volume 244, pp 362-364. KUO ET AL 21 April 1989 see abstract.	18,19,22

* Special categories of cited documents: ¹⁰

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

28 MAY 1990

Date of Mailing of this International Search Report

13 JUL 1990

International Searching Authority

ISA/US

Signature of Authorized Officer

NINA OSSANNA

S. Ossanna, Please for

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

Continuation of Classification:
IPC(5) C12N 1/11,15/02,51 C12P 21/02; C12Q 1/68;
G01N 33/53

V. OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE¹

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. Claim numbers _____, because they relate to subject matter¹² not required to be searched by this Authority, namely:

2. Claim numbers _____, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out¹³, specifically:

3. Claim numbers _____, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING²

This International Searching Authority found multiple inventions in this international application as follows:

1. As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.

2. As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:

3. No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:

4. As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- The additional search fees were accompanied by applicant's protest.
- No protest accompanied the payment of additional search fees.